AUTOMATIC PATENT CLASSIFICATION USING SUPPORT VECTOR MACHINES AND ITS APPLICATIONS

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ABSTRACT

Patents as an important component belonging to innovation can serve as an index in representing the technological development level in a given industry. However, agricultural biotechnology patent (ABP) data have not been updated since 2000. The major objective of this thesis is to identify ABP issued between 2001 and 2007. Apart from traditional manual identifying methods, we focus on adopting a model built on machine learning methodology. As a result, a score will be generated for each patent to indicate its possible inclusion in the agricultural biotechnology category. We select patents based on ranking their scores and following the patent classification scheme. The analysis of 9,539 ABP issued between 2001 and 2007 shows that the quantity reaches its peak value in 2001 and follows a downward trend until 2006. Based on the patent identification result, we also run several economic analyses to verify the ABP development trend and investigate their characteristics.

BIOGRAPHICAL SKETCH

Yan Zhao was born in a small but lovely city Handan of China in 1983. She finished her pre-college education in Handan and went to Singapore to pursue her undergraduate degree of Computing in National University of Singapore (NUS). She received her Bachelor of Computing degree with Business Focus from the NUS in 2006. After that she worked at Singapore Turf Club as a Racing Executive and Webmaster. With a goal to always learn and upgrade herself, she decided to apply for graduate programs to expand her knowledge base. In 2008, she was admitted by Cornell University and expects to receive her Master of Science degree in Applied Economics and Management in August 2011.

This thesis is dedicated to my beloved parents.

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LIST OF ABBREVIATIONS

ABP	Agricultural Biotechnology Patents
Ag-bio	Agricultural Biotechnological
USDA	United States Department of Agriculture
USDA/ERS	United States Department of Agriculture Economics Research Service
USPTO	United States Patent and Trademark Office
M&A	Merger and Acquisitions
R&D	Research and Development

CHAPTER 1

INTRODUCTION

1.1 Background and Motivation

The agricultural industry is widely regarded as a basis for most countries. If we consider the whole world as a supply chain system, the agricultural industry serves as a first level source to provide energy to other industries, and meanwhile supplies necessities to guarantee people's quality of life. Agricultural biotechnology highly incorporates important biotechnologies such as methodologies in plant breeding, variety diversification, genetic engineering, and genetic modification.

The history of agricultural biotechnology development consists of various graduated technology improvements plus several revolutionary innovations that led to sustainable progress. The green revolution that occurred between 1943 and the late 1970s successfully inaugurated a new agricultural era with high-yielding varieties of food crops (Briggs, 2009). Other significant impacts including: improving agricultural facilities and tools, such as the expansion of irrigation infrastructure; and the use of synthetic fertilizers and pesticides, which helped transfer India's agricultural development to a higher standard industrial agriculture stage (Larson *et al.,* 2004).

Besides the benefits brought to developing countries, the revolutionary impacts have greatly impacted the rest of the world.

Hybrid seed is the seed produced by using artificial cross-pollination. A big advantage of the hybrid seed is to reduce the original weak characteristics of the resulting plant, and improve its yield, uniformity, color, and disease resistance. It was one great contribution to agricultural development in the last century and still plays a predominant role today.

Genetic Engineering later notably implemented the idea of modified plant genes to reduce natural plant breeding weaknesses. However, due to various political, legal, and religious issues, genetic related technology is also criticized for the aggressiveness of its implementation. In the early 1990s, the public understanding and acceptance of genetically engineered food was still at a low level. That situation remained the same even after the commercialization of genetically engineered food was initiated in 1994 (Frewer *et al.,* 1996).

At a macroeconomics level, agricultural biotechnology innovation can be treated as an important solution for worldwide food and security problems (Taylor and Cayford, 2004). Senior officials of the current U.S. administration emphasize at international forums the importance of agricultural research capabilities in developing countries in order to overcome poverty and food shortage. Lalitha (2004) believes that any new

technology in agricultural biotechnology that can increase productivity and lower cost will also help solve the poverty problem in a direct way, and moreover stabilize food prices and create more employment opportunities to benefit poor people.

With the advanced development of agricultural biotechnology and its large potential impact on the agricultural industry, there should be a sophisticated legal system not only to standardize its innovation regulation and motivate invention in that industry, but also to guarantee a safe and justice-oriented direction. This leads to an important aspect which is also the major topic in this thesis – Agricultural Biotechnology Patents.

Agricultural Biotechnology Patents (ABP) categorize broadly patents utilizing biotechnology in agricultural industry, and more specifically, improving products or processes in agriculture industries by using organisms or parts of organisms[1]. The United States Department of Agriculture Economic Research Service (USDA/ERS[2]) has published the statistical summaries of its categorization of Agricultural Biotechnology Patents granted from 1976 to 2000, selecting from two million utility patents issued within the same time range. Following a systematic procedure, the USDA/ERS identified a total of 11,073 Agricultural Biotechnology Patents[3].

[1] http://www.ers.usda.gov/data/agbiotechip/filtering.htm

[2] The United States Department of Agriculture Economic Research Service

[3] http://www.ers.usda.gov/data/agbiotechip/Data/Table01_UtilityPatentsByTechnologySummary.htm

The ABP data file produced by the USDA/ERS has been used in several areas including gaining insights into where ag-bio research is being conducted. Possibly due to the merger and acquisition activities by large corporations in agricultural biotechnology, such as DuPont and Monsanto in the late 1990s, innovation has been declining in a new higher concentrated industry environment (Brennan *et al.,* 2005).

ABP can also be divided into two groups according to the organizational type of their assignees. Assignees relying on government based public financing sources are treated as public type, and the ones financed by their own capital or stock issuance are treated as private type. The comparison of public sector and private sector is also a popular area of research.

However, the USDA/ERS has not updated its Agricultural Biotechnology Patents database since 2001. Other patent organizations such as The United States Patent and Trademark Office (USPTO) and other international patent research centers do not conduct any ABP updating work either. The missing ABP data from 2001 through the present have already created a decade-long gap. Consequently, ABP-related research is facing a truncation problem in source work and challenges the accuracy and sustainability of the relevant research output.

1.2 Objective

This thesis focuses on updating and expanding the database of Agricultural Biotechnology Patents granted from 2001 to 2007. Even though our focus is centered on the agricultural biotechnology field, the method we propose can possibly be broadly applied to automatic classification of other patent categories.

Our identification procedure is different from the classical and empirical patent identification methodology. Previously, similar research conducted by the USDA, CAMBIA[4] and other research groups required a significant amount of manual selection effort by experts in agricultural biotechnology fields. In contrast, we apply machine learning and information retrieval methods to solve this identification process in a quantitative way.

With the completion of the identification work, economic analysis on the following three aspects will be presented:

1. Merger and Acquisition (M&A): We will provide case analyses for the top two firms in the agricultural biotechnology industry – DuPont and Monsanto. We concentrate on comparing the differences in several ABP characteristics, such as ABP quantity, class composition, and the participation of class 800 and 435 before and

[4] An Australian based independent non-profit organization doing research about patents and innovations

after the active acquisitions done by each firm. Meanwhile we will explore the possible reasons causing these differences.

2. Public Sector versus Private Sector: We are planning to analyze the public-private industry structure by comparing the percentage held by each sector in the 1976-2000 range and in our new database of 2001-2007 range. With the public and private agricultural research expenditure data obtained from the USDA, we will be able to calculate the agricultural research productivity as the number of ABP per million research dollars spent in both public and private sectors and then compare the trends of these two productivity values. In the meantime, the class composition of patents under both the public and the private sectors will also be explored.

3. ABP vs. Overall Utility Patents: Apart from the clearly developing trend of agricultural biotechnology patents, it is also important to know how the number of ABP developed compares to the overall utility patent number. Some common macroeconomic factors, such as GDP, inflation index, and unemployment rate, can simultaneously influence both the ABP quantity and the overall patent quantity. By considering a relative figure of ABP to the overall patents, we would be able to diminish the effects of the macro-level factors and focus on the unique factors in dominating the real development of ABP, which would be more clearly revealed by the relative figure of ABP to the overall patents.

4. International ABP: The participation of international applicants in applying for patents through the USPTO increased over time. We will conduct case analyses for four selected representative countries: Germany, Japan, Australia, and China. We are interested in knowing the evolving conditions of ABP filed of these four countries while investigating the differences in class composition of these four countries.

CHAPTER 2

LITERATURE REVIEW

An important purpose of patents is to protect the patent owners' intellectual property rights to guarantee a right of using, selling, modifying and re-producing their inventions within a limited amount of time (Guo and Gomes, 2009). The owner of a patent is its assignee or inventor, which depends on the relationship of its assignee and inventor. Patent inventors need to submit applications to a government based authority, and claim the novelty of their innovations. The assignee is a person, a group of people, or an entity who ultimately owns the patent. Normally patent inventors are employees working at an organization which is the patent assignee, but in some cases, individual inventors are also assignees themselves[5].

2.1 Introduction of Patents

Before we examine any details about agricultural biotechnology patents, it is necessary to introduce a patent's basic attributes. A patent contains both qualitative and quantitative variables. Below are some representative and important components of a patent.

[5] http://www.uspto.gov/web/offices/pac/mpep/documents/2100_2137_01.htm

Qualitative Attributes

Patent Title: A simple title describing the main content of a patent

Patent Abstract: A short description of a patent's detailed content

Inventor: The name and the registered residence of the people who discover the invention

Assignee: The name and the registered residence of the people or entity who own the patent

Main Class Number: The number assigned to the general category of a patent regarding its common subject matters

Sub Class Number: The number assigned to the specific category of a patent regarding its common subject matter

Quantitative Attributes

Patent Number: An unique code consisted of integers plus letters to serve as a patent's identification number

Application Date: The date when an owner submitted a patent application for his/her invention

Approval Date: The date when a patent applied for before was approved

Citation Received: Citations received from other patents of similar topics

Citation made: Citations made by patent applicants to other previous existing patents of similar topics

Patent data shown on the USPTO's website contain additional attributes, such as the application number, references, and claims. However, in this thesis, only the above listed variables are necessary for our research.

In the following methodology section, we will describe a series of keyword searching procedures in our ABP identification work. The qualitative variables containing textual information are important data source for ABP identification. The quantitative variables that have numeric information can help accurately allocate searching ranges in patent datasets.

The patent application date and approval date are both important. In this thesis, we define a patent's date to be its approval date, because a patent is formally issued only once being approved. The USDA, which has adapted a fairly systematic and scientific identification methodology and which we use as reference, also treats the approval date as the official date of a patent. There are some different opinions about the definition of a patent's date. As some patents are issued after a long reviewing period, only considering the approval date may unfairly treat those patents approved after a long wait. Foltz and his colleagues adopted the application date, which they believe was more significant in their econometric model (Foltz *et al*., 2003).

Although the main class number and the subclass number are in numeric formats, in

our identification procedure the classification system only serves as categories to differentiate patents. We treat each class and subclass as categorical variables.

2.2 The development of ABP

In the early days, the permitted patenting categories were very limited, such as the subject matters in machines, compositions of matter, articles of manufacture, processes, or the improvements in each (Sease, 2007). Patents at that time did not involve any information regarding living organisms. The reason could be due to some conflicts with religious beliefs, ethical issues, and the pressure from government policies. In 1953, the structure of DNA was discovered by J.D. Watson and Francis Crick, which inspired people to modify genes of living species in order to produce higher standard benefits (Sease, 2007).

With the development of genetic engineering technology, there needed to be a corresponding change in the patent regime as otherwise patent law would impede the accelerating progress of agricultural biotechnology. However, this progress was slow and the non-patentability of most living organisms dominated until the 1980s. The famous Diamond v. Chakrabarty case (Lumelsky, 2005) aroused a large amount of controversy regarding whether living things could be patentable. The genetic engineer Chakrabarty genetically modified a bacterium and submitted a patent application to the USPTO. The application was rejected because of the non-patentable subject matter. A Commissioner of Patents and Trademarks, Sidney A. Diamond, appealed this case

to the Supreme Court. The patent regulations were updated according to the decision making subject matter such as live human-made micro-organisms patentable from then on.

In the 1980s, genetic modification technology started to demonstrate advantages in increasing plant quality and bringing various benefits to the agricultural industry. The patentability in the agricultural biotechnology industry also grew rapidly, and boomed after 1996 two years after the commercialization of genetically engineered products was initialized.

The patent inventor can be a single person or a group of people. Normally inventors are employees working for the assignee which is either a private company or a public research institution. In this thesis, the owner of a patent is equivalent to the assignee of that patent. We define the organizational type of patent assignee according to its form of financing. An assignee relying on government-based public funding is treated as a public type and an assignee depending on its own capital fund or financing through stock issuance is treated as a private type. At the macro-level, we refer to them as the public sector and private sector.

Graff and his colleagues (2003) identify the public sector as a driving force in the

development of agricultural biotechnology. After the Bayh–Dole[6] Act in 1980, universities and small business entities were allowed to patent inventions resulting from using federal government research funds, which further motivated the public sector to innovation and patentability.

Universities with higher academic performance and research capabilities, as an important component under the public sector (Foltz et.al, 2000), contributed significantly to the first generation of technology innovation. The private sector conducts research driven more by commercial profits, so they probably prefer to focus on the existing innovations with potential commercial values.

Public sector agricultural biotechnology production depends on the infrastructure of local universities and economic conditions (Foltz *et al.,* 2000). However, the private sector still dominates the quantity of agricultural biotechnology patents in developed countries (Graff *et al.,* 2003). In the ABP statistics provided by Graff and his colleagues, the number of ABP innovated by the private sector is three times the quantity innovated by the public sector.

However, this is weak evidence to conclude that the public sector did a worse job in their research development. Simply counting the quantity of patents is an imperfect

[6] United States Congressional Research Service, Patent Ownership and Federal Research and Development (R&D): A Discussion on the Bayh-Dole Act and the Stevenson-Wydler Act, December 11, 2000

way to evaluate patent value (Lanjouw, Pakes and Putnam, 1996), as patent values vary substantially due to different contributions to current and future knowledge. Several researchers have raised more refined valuation methodologies, such as considering citations as weights (Hall, Jaffe and Trajtenberg, 2000), which means to calculate the value of Tobin'q by using Research and Development (R&D) expenditure to transfer patents to citation-weighted patents. This thesis does not focus on ABP valuations, but we have to declare this bias at the beginning to give a clear understanding about the contributions from the public and private sector.

Agricultural biotechnology patents owned by international assignees in other developed countries reveal a similar private-public structure. The patents issued to European and Japanese owners are the largest two components in the international pools. This is easy to understand because Western Europe and Japan are probably the representative developed regions besides the United States, so their matured patent regulation systems and advanced academic research capabilities can help drive their innovation performance. Germany and Japan have demonstrated their efforts to improve their biotechnology research framework and advantage (Lehrer and Asakawa, 2003). In the ABP statistics provided by Graff and his colleagues, the quantity of Japanese-based ABP is about 90% of that of the U.S. one, and the European based ABP quantity percentage is about 65%.

On the other hand, developing countries, though having some constraints in their

intellectual property regulations, started to invest in agricultural biotechnology innovations as well (Dookun, 2001). China introduced and commercialized genetic modified crops just after the USA, Argentina, and Canada (Huang *et al.,* 2004). Because of the slower rate of development of its agricultural technology and the huge pressure from having the world's largest national population, the need for more agricultural biotechnology to increase productivity and production for China is great. Differing from developed countries, the public sector in China plays a dominating role in contributing agricultural innovations (Huang *et al.,* 2004). The reason could be due to its centralized authority system in politics and social administration.

2.3 USPTO Patent Classification

The USPTO adopted the U.S. Patent Classification System (USPC) to establish its patent classification scheme. The system is used for grouping patent documents or many other technical documents with common subject matters together. The first level division based on common subject matter is "class", which means categorizing patents according to their most general subject matters. The second level division is "subclass", which is to categorize patents according to their more specific subject matters under each class[7].

[7] United States Patent and Trademark Office. 2010. *Overview Of The U.S. Patent Classification System (Uspc), 1-16.* Alexandria, VA, December.

A unique patent code is assigned to each patent class. Each class then is sub-divided into more specific subclasses. In order to be more accurate, in this thesis, we refer the "class number" as the "main class number" to better differentiate it from the "subclass number".

An identifier in the format of "main class number/subclass number" accurately indicates a subclass under a main class. For example, a patent about a novel soybean cultivar with a patent number 5929309 is filed under 800/312 classification, which is the "soybean" category under major class 800 and subclass 312.

In the USPTO patent classification system, the main class numbers under the utility patent categories are purely integer numbers, while the main class numbers of the design patents are in the format of the initial letter "D" followed by integers. Besides the large number of utility patents and design patents, there is one class named "G9B" to represent "information storage based on relative movement between record carrier and transducer"[8] and another one "PLT" denoting plants.

The USDA considers seven main class numbers[9] which are closely related to agricultural biotechnology definitions, and which are listed below:

Class 800: Multicellular Living Organisms and Unmodified Parts Thereof and Related Processes

[8] http://www.uspto.gov/web/patents/classification/uspcg9b/schedg9b.htm

[9] http://www.ers.usda.gov/data/agbiotechip/classification.htm

Class 935: Biotechnology

Class 435: Chemistry: Molecular Biology and Microbiology

Class 47: Plant Husbandry

Class 424: Drug, Bio-Affecting and Body Treating Compositions

Class 514: Drug, Bio-Affecting and Body Treating Compositions

Class 504: Plant Protecting and Regulating Compositions

With an evolving technology, the patent classification and categories also change. Class 935 has been terminated and the patents under this class have been reclassified into class 800, 435, and 47.

2.4 International Patent Classification

International Patent Classification is another important patent classification scheme. Since we do not adopt this scheme in our patent identification work, we just give a brief introduction to it here.

The classification coding scheme follows a hierarchical style. There are eight main categories, which are listed below[10]:

A: Human Necessities

B: Performing Operations, Transporting

C: Chemistry, Metallurgy

[10] http://en.wikipedia.org/wiki/International_Patent_Classification

D: Textiles, Paper

E: Fixed Constructions

F: Mechanical Engineering, Lighting, Heating, Weapons

G: Physics

H: Electricity

There are nested sub categories under each main category. The format of the classification term can be expressed as a combination of letters and digits, such as "A01B 1/00". The first letter indicates the first level main categories listed above. The main category is followed by a two digits class symbol indicating the main class of a patent. The final letter plays a role as a subclass indicator to finalize the whole classification procedure. The second part consisting of two digits, one slash and another single digit serves as a group index. The first two digits represent the main group and the last one represents the subgroup. The grouping indicator can help identify a patent's specific topic more accurately (WIPO, 2007)[11].

2.5 Previous ABP Identification Work

Several research institutions have conducted ABP identification projects using different selecting criteria under different selecting domains.

[11] World Intellectual Property Organization. 2007. Guide to the International Patent Classification, Geneva, Switzerland, October.

The United States Department of Agriculture (USDA) is the federal executive department in the United States in charge of administration matters and policy execution in farming, agriculture, and food. As mentioned in the introduction section, the USDA has identified 11,073 agricultural biotechnology patents by following a systematic procedure[12]. They first filtered the U.S. patents using International Patent Classification, followed by separating plant patents and utility patents. After the initial selection, they applied an agricultural biotechnology key words list and an agricultural biotechnology firm list into their filtering criteria as well, to include patents matching the two lists. In addition, they took the U.S. patent classification information into account to give certain class numbers priority in consideration.

CAMBIA is a private institution carrying out research mainly on agricultural biotechnology innovations with an international concentration. It focuses on building searching functions for Japanese and Australian patents related to agricultural biotechnology. CAMBIA cooperated with the USDA in doing the 1976-2000 ABP identification project. The USDA initially obtained the raw U.S. patent data from the United States Patent and Trademark Office (USPTO) and sent a copy to CAMBIA for further identification. In exchange, CAMBIA created a subset of 130,000 patents based on the relevant agricultural biotechnology international classification codes for further investigation.

[12]http://www.ers.usda.gov/data/agbiotechip/filtering.htm

Apart from the public research institutions, some groups of research fellows also conducted similar but smaller sized ABP identification work. Foltz and his colleagues (2003) have identified a list of 800 ABP owned by universities based on a standard of patent classification. With a narrower focus on only university owners, they specified their selections into two sections: inclusion and exclusion. They included patents under class 800 and 435 which are mainly about multicellular living organisms, molecular biology, and microbiology, and patents about usage, modification, or improvement in products produced on farms, or food, wood or aqua-cultural products. At the same time, they excluded patents about products or processes relating to animals, vaccination techniques or human diseases.

Graff and his colleagues (2003) also created a 4,300 ABP list by following a similar keywords matching algorithm using a software called ThemeSpace produced by MicroPatent. This software was able to cluster patents according to their thematic proximity, so patents with similar text information were distributed closely to each other. The final list of agricultural biotechnology patents were determined by selecting the desired patents within corresponding clusters. These two small datasets were used as important references in the USDA ABP identification project.

CHAPTER 3

METHODOLOGY

3.1 ABP Dataset

The raw patent data we obtained cover a time range from 2001 to 2009. However, the patent data granted from 2007 to 2009 have serious problems such as format changes and missed patent citations. Those problems cause inaccuracy and inconsistency in the whole dataset, so in this thesis we only consider ABP in the range between 2001 and 2007. According to the characteristics of the patent datasets, we have divided them into four categories, as indicated below.

TrueABP7600: This dataset is the 11,073 agricultural biotechnology patents granted between 1976 and 2000 identified by the USDA, which is also an important reference in our identification procedure.

TotalPatents7600: This dataset is the raw patent data granted between 1976 and 2000 including not only the agricultural biotechnology fields but all patents filed under all the categories, which were purchased from the USPTO.

TotalPatents0107: Similar with the dataset **TotalPatents7600**, this dataset includes

all the patents issued between 2001 and 2007. Based on this dataset, we conduct our own identification procedure to predict the new generation of ABP.

To be consistent with the above naming standard, we name the ABP database to be identified as **TrueABP0107**, which means the ABP granted between 2001 and 2007. We refer to these abbreviated terms throughout this thesis for convenience.

3.2 Brief Introduction about Machine Learning

Our methodology to identify ABP builds considerably on Machine Learning theories. Machine Learning is a sub-category of artificial intelligence that is a branch of computer science dealing with study and design of intelligent agents (Poole *et al.,* 1998). Machine Learning incorporates science and engineering methodologies to develop algorithms to automatically recognize complex patterns from empirical data and make intelligent decisions based on that data. Before we explore the details of the methodology, it is necessary to give a brief introduction about all the terminologies involved in our patent classification context.

Training Set: A dataset consisting of input vectors and a response vector, where each element of the response vector corresponds to a true classification of an input vector. One goal of a machine learning algorithm is to construct an accurate model based on the input vectors to predict the response vector.

Test Set: A dataset which is independent of the training set but which follows the same distribution. Prediction can be conducted by using data from test set and the model derived from the training set.

Parametric Model: A model built assuming certain underlying distributions described by a set of parameters. The typical form by using these parameters is an n-dimensional vector such as $\theta = (\theta_1, \theta_{2,} ... \theta_n)$.

Non-parametric Model: A model making no assumptions with input to the dimension of the data, which is not dependent on data in any particular distribution.

The major practical difference between a parametric model and a non-parametric one is whether the training instances are needed after the model has learned to predict testing instances. For a parametric model, all that is needed to make future predictions is the parameter set θ, such as in a linear regression model. On the other hand, a non-parametric model needs to memorize the training instances to make predictions, such as the K nearest neighbor classification method.

Parsing: A methodology to process text information by analyzing it in the units of tokens, such as words, according to its grammatical structure and rules, and extract structural information, such as patent class number, assignee companies and number

of claims.

Learning: An implementation by a computer program to optimize the modeling by using training data or past experiences (Alpaydin, 2004). The goal is to make accurate predictions for future unseen data of similar structure as the training data.

Information Gain: A measure widely used in Artificial Intelligence to gauge the contribution of a feature in making an accurate prediction. We use this measure to select the most informative words to classify an ABP.

Features: A group of individual properties being evaluated or determined for a phenomenon or an object. For the patent dataset, example features include number of patent applicants and year of application.

Feature Vector: An n-dimensional vector consisting of numeric features to characterize an object. A textural patent is represented or parsed as a numeric feature vector before the learning algorithm could utilize it.

3.3 ABP Identification Procedure

We have mentioned that the USDA considers seven major class numbers as the most representatives of agricultural biotechnology definition. Initially, we questioned

whether the selection of the currently actively used six classes would cover an adequate ABP range. Therefore, by assuming this is true, we examine whether the number of ABP filed under the six class numbers in the dataset **TrueABP7600** is equivalent to the total number of patents under the same six class numbers in the dataset **TotalPatents7600**. Here we name the latter as **6ClassPatents7600**.

Table 3.1—Comparison of Patent Data in TrueABP7600 vs. 6ClassPatents7600

Class	TrueABP7600	6ClassPatents7600
47	217	1384
424	987	16836
435	5835	17316
504	144	945
514	242	24286
800	1917	3734

As shown in Table 3.1, there is a large difference in the patent quantity under each class in the two categories. Thus, we can conclude that there must be patents under these six major class numbers that do not belong to the ABP category. As a result, considering only these six class number has to be abandoned. However, because of the strong recommendation from the USDA, patents under these six class numbers are still used as an important reference in our machine learning methodology.

We have retrieved patents satisfying both criteria of classification and patent number. As a result, a combination of both **6ClassPatents7600** and **TrueABP7600** has been generated, and we give it a shorter name "**CombinePatents7600**".

In generating the list of the 11,037 agricultural biotechnology patents for the period of 1976-2000, experts were substantially involved in the identification process. Such a manual effort is expensive to fund now for the newer patents after 2000. In order to generate a more accurate list of agricultural biotechnology patents with significantly fewer false-positive identifications for patents granted after the year 2000, a systematic means of agricultural biotechnology patent classification needed to be developed. Fortunately, using the progress of machine learning models that extract relevant features from large scale dataset and their ability to process such features to make accurate predictions, we aim to construct a parametric machine learning model.

The agricultural biotechnology patents of 1976-2000 are used as the training set, to form a predictive model to identify patents under **TotalPatents0107**. We choose a parametric model, the Support Vector Machines (SVM). This is because a parametric model learns a set of parameters from the training set, and during the testing phase the training instances are not needed given those learned parameters. On the other hand, a non-parametric method would require the learning algorithm to remember the patents in the training set during the testing phase, which puts a heavy burden on any reasonable learning algorithm. In the next section we will describe the patent representation problem.

It may sound unfamiliar to apply Support Vector Machine (SVM) methodology to select patents. However, this methodology has been adopted for identification in other

fields. Huang and his colleagues (2004) applied the SVM method to identity firms' credit rating levels based on their published financial ratio data in both the United States and Taiwan markets. However, our patent identification only has a binary classification, that is whether a patent belongs to the ABP category or not. Their credit rating level has multiple categories. Huang and his colleagues (2004) showed that the model built by the SVM method has a better explanatory power, and their identification results showed that SVM was more accurate than the one generated by another method, Back Propagation Neural Network.

We have checked the evolving classification information of these six major class numbers on the USPTO webpages "Classification Orders"[13] and "Classification Orders Index"[14]. These six class numbers have not been terminated or reclassified from 1976 to present, and the only modifications are the adjustments to their subclass numbers.

The size of the training dataset, which is also the **CombinePatents7600**, is very large with more than 130,000 patents. Each patent is a textual document. We need to covert the textual content of a patent to a numeric vector, as an efficient learning algorithm often requires input instances to be expressed as numeric vectors.

As mentioned in the literature review section, a patent is a collection of multiple

[13] http://www.uspto.gov/patents/resources/classification/orders/index.jsp

[14] http://www.uspto.gov/patents/resources/classification/orders/coi.jsp

qualitative and quantitative variables. The variables Patent Title and Patent Abstract are full of textual information. Generally, the Patent Title briefly describes the purpose of that patent and the Patent Abstract provides details about the methodology, and process involved in designing that patent.

With our purpose to reduce manual investigating effort and apply automatic patent checking procedures, creating a standard agricultural biotechnology definition becomes a critical problem. Because patents in the dataset **TrueABP7600** are defined as official ABP by the USDA, the textual information from these patents can be treated as an aggregate collection of definitions. Therefore, how to transfer that textual information into numeric formats becomes another problem in our methodology, because for a machine learning approach to efficiently build a predictive model, the patents must be represented as fixed-length numerical vectors.

A Bag-of-Word representation is often used as the vector space model for textual information. This representation treats each unique word appearing in the collection of documents as a single feature, resulting in more than 100,000 total features to represent each patent. Following the work and recommendations in Salton and Buckley (1988), we also use the bag-of-word model to construct such a representation. Given the training set patents, we first combine all the words appearing in the 1976-2000 ABP dataset, and apply the stemming and stop word removal to reduce the word set*:*

***Stemming**:* a word is reduced to its "root form". For instance, *running* reduces to *run* and *genes* to *gene*.

***Stopword Removal**:* any frequent but uninformative word, such as *the* and *again,* are removed.

After the above two steps, we have about 120,000 unique terms from all the patens in our training set and testing set. The vector size to represent each patent is thus 120,000, with one element corresponding to one unique word. However, because most patents only contain less than 1% of all possible unique words appearing in the whole patent dataset, the vector representation of those patents would have many zeros in the corresponding positions of the missing words. This sparseness feature of the vectors allows us to efficiently store and process these patent vectors in our learning approach.

In our experimental studies, we use a word's information gain in the training set to select the top 1000 word terms from the total of 120,000 possible unique terms. Therefore, our feature vector representation of a patent is always of length 1000. The value 1000 is chosen experimentally to keep the optimization efficient. In addition, by not including too many words we can reduce overfitting, which often results from complex and excessive features.

To successfully classify patents, the Bag-of-Word representation model needs to be combined with proper term weighting and normalization schemes. This is because the simplest bag-of-word model only indicates the existence on a word in a certain patent, and it can unfairly favor common words, such as “introduction”, “numeric” and “date”, that appear in many ABP but actually contain very little relevant information of a patent’s nature. There have been extensive studies on how to improve model prediction performance by selecting the suitable space vector model weighting scheme in text categorization. For an empirical comparison of different weighting methods, refer to Salton and Buckley (1988).

Next, we need to determine how to calculate the values of patent feature vectors. In our application, each feature vector has a length of 1000 and the 1000 numeric elements represent the weights of the selected words in a given patent. A simple way of weighting is to use the number of occurrences of the word in a patent. In such a weighting scheme, we assume that a frequent word in a patent requires more attention from the learning algorithm, compared with a less frequent word. One drawback of this simple scheme is that some words, as we saw in examples above, although they appear frequently in agricultural biotechnology patents, also appear frequently in non-agricultural biotechnology patents.

In general, words that appear in many documents are not as informative as words that mostly appear only in agricultural biotechnology or non-agricultural biotechnology

patents. Consequently we use the Term Frequency Inverse Document Frequency (TF-IDF) weighting scheme (Salton and Buckley, 1988). The TF-IDF weight of a word q in the patent p is calculated as $\frac{n_{pq}}{d_q}$, where n_{pq} is the number of times the word q appears in p, and d_q is the number of patents q has ever appeared. The current weighting scheme also unfairly favors long patents as the longer the patent, the more likely a word would appear multiple times. Since there is no reason to believe that a longer patent is a better candidate of an agricultural biotechnology patent, we normalize the Euclidean norm of each patent vector to have the unit length. With the TF-IDF weighting and vector normalization, the sparse patent vectors can be efficiently processed during the SVM training phase.

3.4 Learning Model Formulation

SVM is a classical machine learning method with a wide range of applications, which first appeared in Vapnik's paper "The Nature of Statistical Learning Theory" (1995). It aims to find a separating hyperplane that divides all positive instances from all the negative instances in a binary classification problem. The SVM formulation for binary classification is as follows:

$$\min_{w,\xi} \| w \|^2 + C \sum_{i=1}^{n} \xi_i$$

Subject to

$$y_i(w^T \phi(x_i)) \geq 1 - \xi_i$$

$$\xi \geq 0$$

x_i is the vector representing patent i. y_i is the patent class label and it can be either 1 or -1, indicating if patent i is ABP. The decision variable w is a vector outcome of the quadratic optimization and it describes the separating hyperplane learned from the training patents. A separating hyperplane is effectively a decision boundary largely determined by w: every patent that falls on one side of the hyperplane is classified ABP, while all other patents that fall on the other side of the hyperplane are classified non-ABP. There are two terms in the minimizing objective function: $\| w \|^2$ is related to the margin size of the separating hyperplane SVM optimizes for (the smaller the norm is, the larger the margin of the separating hyperplane becomes), and $\sum_{i=1}^{n} \xi_i$ is the misclassification error we will make in the training patents.

Constant *C* controls the weight of the two terms and it is often viewed as a trade-off between the size of the margin and the level of error we can tolerate. In our experiment, we varied C from 0.01 to 1000 to find the most accurate automatic ABP classification model over a range of 0.02 possible objective functions in SVM.

The goal of the optimization is to find the decision variable vector w that when presented with an agricultural biotechnology patent x_i, the scoring $w^T \phi(x_i)$ is positive and large and when presented with a non-agricultural biotechnology patent, the scoring function gives a negative number. $\phi(x_i)$ is the feature map function on a patent vector. It can be the same as x_i if a linear kernel is used, or it can be an implicit function that maps the input vector x_i to a higher dimensional space where a

linear separating hyperplane can differentiate agricultural biotechnology patents from the rest.

This formulation is a quadratic convex programming and can be efficiently optimized. We use SVM-light (Joachims, 2002) to solve the formulation. Once w is obtained, a new patent is classified to be agricultural biotechnology if $w^T \phi(x_i) > Q$, where Q is a threshold constant normally set to be 0. Apparently the smaller the Q number is, the more patents we would classify as ABP. In fact we found that the Q value should be patent class specific. We will discuss how we dynamically adjust the patent class specific Q value to keep our predicted ABP proportional to the real ABP in the training set.

In the experiment result section we will present our performance evaluations using both a linear kernel function for the feature map $\phi(x)$ and two non-linear ones, namely the polynomial and RBF kernels. Therefore, $w^T \phi(x_i)$ is regarded as a score to represent a degree of qualification. In our patent data, we name it as patent score, which indicates a possibility of qualification for ABP definition.

3.5. Prediction Performance

3.5.1 Evaluation Measure Discussion

Accuracy rate is often the major prediction measure for a classification task, which is defined as **Accuracy Rate =** $\frac{\textbf{Number of correctly predicted patents}}{\textbf{Total number of predictions}}$

The number of correctly predicted patents refers to the sum of the true ABP predicted to be ABP and the true non-ABP predicted to be non-ABP. However, this simple accuracy is not a good evaluation metric for our application. Based on our methodology, it may not be easy to identify ABP accurately according to the historical representative keywords, but it is not difficult to identify non-ABP as we treat patents with weaknesses in qualifying ABP to be non-ABP. When we applied this simple accuracy calculation in our **TotalPatents7600** dataset where we already know that there are 11,073 ABP, the accuracy rate is as high as 91.3%.

Depending on the application domain, prediction accuracy may not be the best evaluation metric if the class labels are unbalanced, which means the number of non-ABP is much larger than the number of ABP. In our case, the agricultural biotechnology patents consist of less than 10% of patents in the training set from 1976-2000. Hence, the large portion of non-ABP inflates the accuracy rate for being easily determined. Identifying some suitable metric is a key to building a reliable classification model. Some of the relevant measures are *precision* rate and *recall* rate. Since accuracy alone is not a very useful measure of performance in an unbalanced learning task, we also adopt the notions of precision and recall from the information retrieval community:

$$\textbf{Precision Rate} = \frac{\textbf{Number of true ABP predicted to be ABP}}{\textbf{Total number of predictions}}$$

$$\textbf{Recall Rate} = \frac{\textbf{Number of true ABP predicted to be ABP}}{\textbf{Total number of true ABP}}$$

In other words, *precision* measures among the patents predicted to be ABP, which is the percentage that they really are; *recall*, on the other hand, measures the percentage of correctly identified ABP among all true ABP in the dataset. Ideally we would like to construct a model that gives perfect scores for both precision and recall, but in practice a higher precision score may lead to a lower recall score, and vice versa.

This is because an algorithm that tries to achieve a high precision score would often be very conservative and classify a patent to be ABP only when the confidence level is high. This may lead to the value in the numerator of the recall formula to be low and therefore a low recall score. Similar argument shows that a higher recall score would likely result in a lower precision score. In our application the precision is more important than recall and we aim to construct our learning model which should have a high precision rate, while maintaining a reasonable recall score.

3.5.2 Experimental Results

We conducted extensive experiments on the patents from 1976 to 2000 with a known positive and negative agricultural biotechnology patent training set to select the most suitable parameter setting of SVM. Referring to the model specified in 3.4, the parameters whose values we varied are the C and the kernel parameter. To obtain

stable performance estimation, we also made use of the 10-fold cross-validation procedure. In other words, we split the dataset into 10 equal parts and ran the experiments 10 times.

Each time we used a different part as testing data, and the other 9 parts as training data. . The final performance measure is therefore averaged over the 10 times for every parameter setting. There are two major advantages of using a 10-fold cross-validation procedure compared with the classical training/testing split: firstly, we can have an averaged evaluation over 10 different trials rather than a single test to reduce result variance; secondly, in each of the 10 trials we can use up to 90% of training data to build an accurate model, while in the single training/testing split we normally use 70% of the data to build the model and the remaining 30% to evaluate. For efficiency, we choose the feature vector of length 1000, corresponding to the top 1000 words in the data corpus by the word's information gain in the training set.

We varied the C parameters from 0.01 to 1000 and the kernel option among no-kernel, polynomial kernel and RBF kernel. The relevant results are presented below. In the kernel column of the table, d is the degree of the polynomial kernel and γ is the constant used in a Gaussian function, which is often reparameterized as $1/2\sigma^2$ with σ^2 being the variance. When we use a linear kernel function we simply indicate "None" in the kernel column.

Table 3.2—10-fold cross-validation results for patent categorization

C	Kernel	Precision (%)	Recall (%)	Accuracy (%)
0.01	None	81.9	26.9	93.2
0.1	-	81.3	38.8	93.9
1	-	80.6	47.5	94.4
10	-	79.2	49.6	94.5
100	-	78.6	49.9	94.4
1000	-	6.6	41.7	48.6
1	Polynomial d=3	71.6	65.3	94.9
10	-	68.7	65.5	94.6
1	RBF γ =0.1	82.6	44.8	94.6
10	-	**81.0**	**54.2**	**94.9**

As we explained before, among the three evaluation metrics we value precision most and we want to keep a high enough recall score. From the detailed table above we choose C=10 and use the RBF kernel with γ=0.1 because the precision score of 81% and recall score of 54.2% satisfy our purpose. Regarding selecting the optimal parameter settings, we take the priority as precision > recall > accuracy, among the choices having the precision score greater than 80, the one with C=10 and RBF kernel with γ=0.1 gives the most impressive recall score, so this parameter combination is the optimal one in our experimental results.

As a result, after running a computer program to implement this methodology on the dataset **TotalPatents0107**, each patent candidate is given a score. The value of that score represents a degree of possibility being qualified for ABP definition, which is an important index in our next patent selection procedure.

In this section we have introduced the quantitative framework of automatic ABP classification based on Support Vector Machines and presented the experimental results using the precision and recall metrics. We used the patents from 1976-2000 as the training set to build a model to classify ABP from 2001-2007. Although this model is constructed to specifically classify any future ABP patent, our methodology, including the numerical patent vector parsing, patent feature construction and binary classification, can be applied to a wide range of patent classification tasks given appropriate training and testing patent dataset. In the next sections, we will describe our application analysis and economic findings based on our ABP classification model.

CHAPTER 4

ITERATIVE ABP IDENTIFICATION PROCESS

This section describes the detailed iterative process of selecting ABP. Iteration is a common approach used in an identification procedure, because generally speaking, an identification of a new object without specific definitions requires various iterations of sampling and simulations to produce a more accurate output. In other cases, if an expected output can be predicted, the iterations will help approximate to that result by running various simulations.

Referring to the methodology section, each patent candidate in the dataset **TotalPatents0107** is given a score. The rationale under this methodology tells us that the higher the score value, the higher the possibility that a patent candidate will be qualified for ABP definition.

Although the real developing trend of ABP is unknown, the statistics of overall utility patents granted after 2000 are published by the USPTO. Figure 4.1 shows a general upward trend. The increase was accelerated after 1996 and there was a slight backward trend from 2003 to 2005. ABP growing trend may have its own specific shape, but because it is one sub-category under the total utility patents, due to the same influences from the common macroeconomics factors such as GDP, inflation,

technology transfer, the ABP trend may evolve with time in a similar general form.

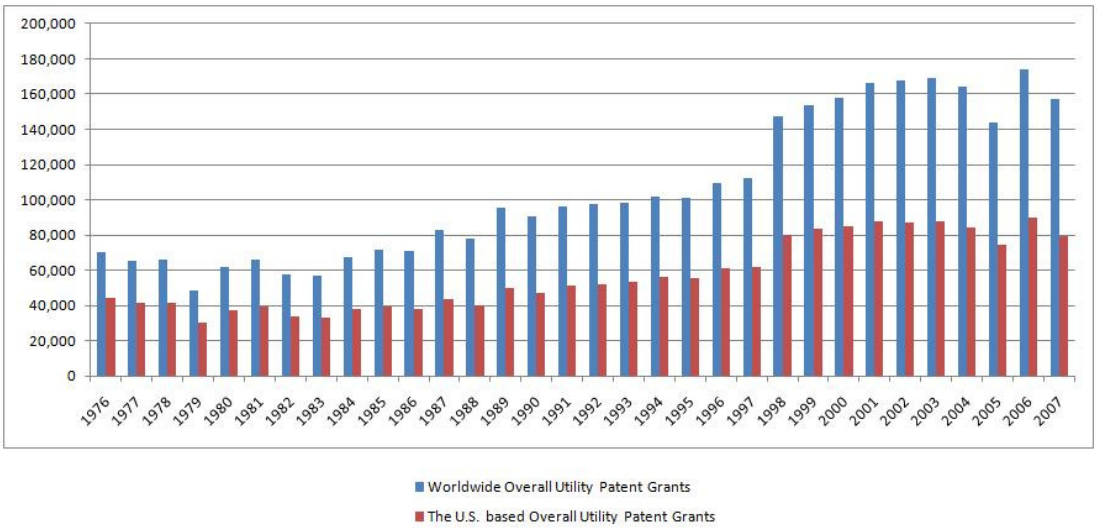

Figure 4.1—The developing trend of total utility patent grants

Brennan and her colleagues (2005) discussed how merger and acquisitions could impact on innovation activities in the plant biotechnology industry. They suggested that a high concentration industry increased by a large amount of merger and acquisitions could be a reason to reduce the innovation activities.

In this section, we have selected patents in a total of five rounds. At the beginning, the selection criterion was conservative by strictly following the regular SVM filtering criteria to only consider patents with positive scores. Since the first round ABP trend was insufficient to catch a similar growing trend compared to the overall patents, we have to include other selecting criteria to improve the predicted ABP quantity in the 2001-2007 period.

4.1. First Iteration by Only Considering Positive Scores and Six Class Numbers

At the first iteration, we tried the most conservative criterion only considering patents with positive scores filed under the major six class numbers. This is a tentative task at the very first round so it is reasonable to narrow down the selection scope. The total number of agricultural biotechnology patents identified by using the first round methodology is **5,927**.

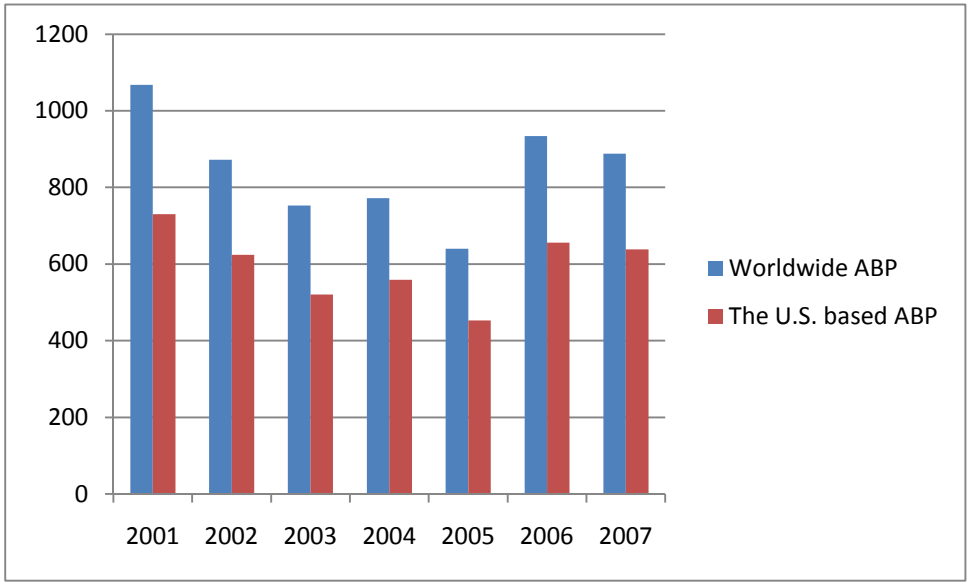

Figure 4.2—The First Round Agricultural Biotechnology Patent Development Trend 2001-2007

Figure 4.3 shows the development trend of the U.S. Agricultural Biotechnology Patent and its dominant figure in the overall worldwide ABP data. The annual histograms show that the U.S. based patents make up the majority of worldwide patents. Applicants in the United States typically file patents in their own country. Meanwhile by being more familiar with the patent regimes, it is more convenient and less costly for them to follow the procedure.

In addition, we can see that the development trend of the U.S. Agricultural Biotechnology Patent is consistent with the overall one, depicting a slight downward trend in the first three years, followed by a drop in 2005. Both numbers reach their peak values in 2007.

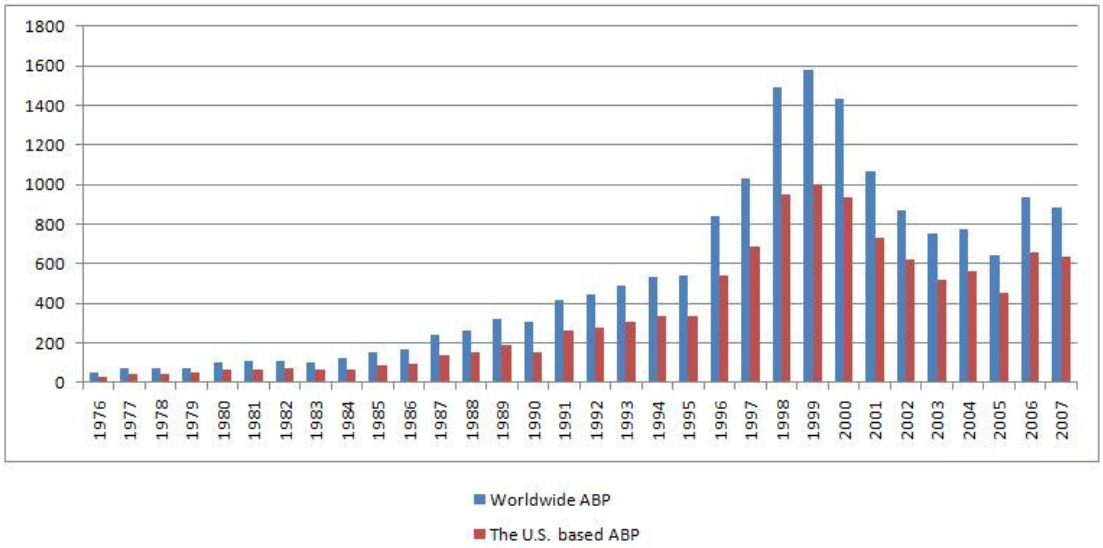

Figure 4.3—The First Round Agricultural Biotechnology Patent Development Trend 1976-2007

However, the first round prediction shows an abrupt drop compared to the ABP quantity in 2000. In order to be consistent with the overall patent trend, more selection criteria have to be added in to broaden the initial consideration of ABP candidates.

4.2. Second Round by Considering Positive Scores and 38 Class Numbers

To overcome the above problem, we have extended the class scope including the number of the USPTO patent classes which appeared in the **TrueABP7600** more than once. The class numbers appearing only once are discarded because we believe that rare frequency may indicate a randomness of occurrence. There are totally 38 classes

(referring to Table 4.1) to be considered this time.

Table 4.1—Class Numbers Appearing in 76-00 Dataset

MainClass	**Frequency**	**MainClass**	**Frequency**	**MainClass**	**Frequency**
435	5835	544	5	84	1
800	1917	210	4	99	1
71	580	438	4	124	1
536	408	135	3	126	1
426	253	162	3	200	1
514	242	252	3	205	1
530	227	395	3	382	1
47	217	428	3	423	1
504	144	449	3	430	1
436	34	534	3	437	1
422	33	560	3	453	1
260	32	106	2	512	1
119	19	232	2	540	1
195	16	264	2	546	1
204	14	427	2	556	1
510	8	455	2	600	1
127	6	549	2	702	1
548	6	7	1	704	1
554	6	8	1	707	1
364	5	11	1	738	1
525	5	53	1	935	1

By only considering the class numbers appearing more than once in the test set and setting the prediction score threshold to be zero, we have identified **6,936** agricultural biotechnology patents issued between 2001 and 2007.

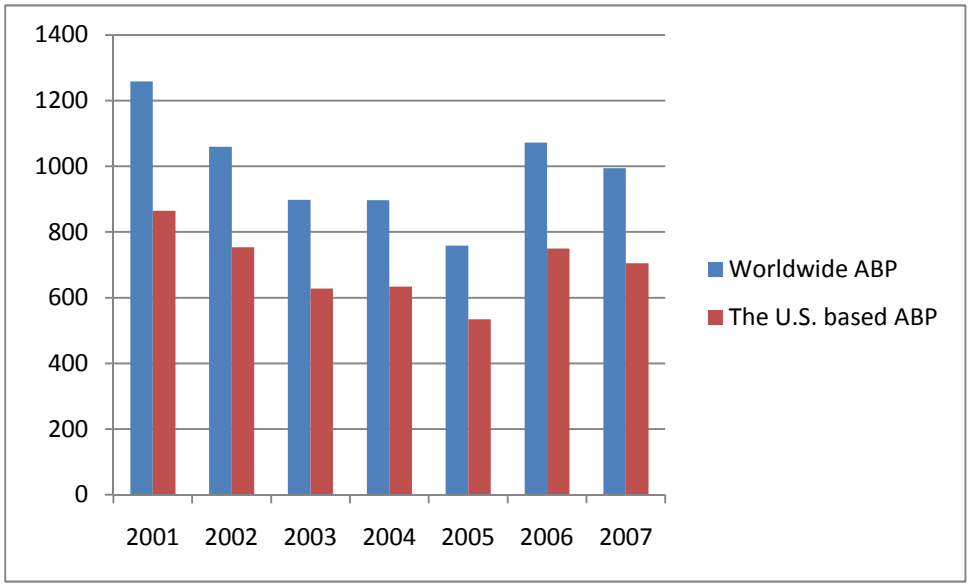

Figure 4.4—The Second Round ABP Development Trend 2000-2007

As shown in Figure 4.4, the number of predicted ABP depicts a peak value in 2001 followed by a downturn from 2002 to 2005. The year 2006 seems to be a start leading a new increasing trend.

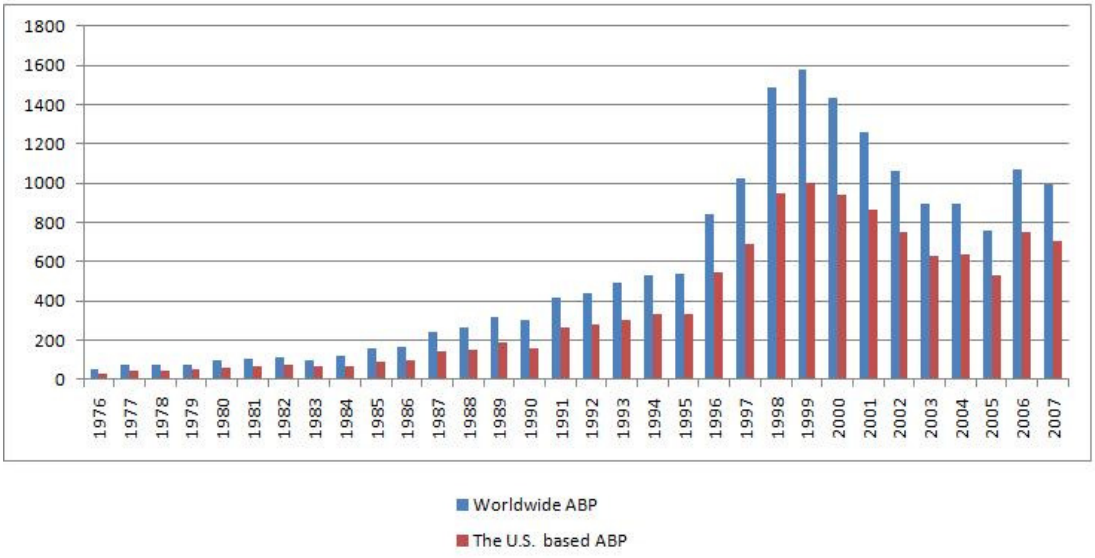

Figure 4.5—The Second Round ABP Development Trend 1976-2007

However, if we combine the 2001-2007 result with the previous statistics from the 1976-2000 dataset, the smoothly increasing trend from 1976 to 2000 is broken by our

predicted Agricultural Biotechnology Patents from year 2001, which is a possible signal that our prediction approach may still be too conservative.

4.3. Third Round by Considering Positive Scores and 36 class numbers

Table 4.2—Updated Class Numbers Appearing in 76-00 Dataset

MainClass	Frequency	MainClass	Frequency	MainClass	Frequency
435	5835	210	4	124	1
800	1917	438	4	126	1
424	987	135	3	200	1
71	580	162	3	205	1
536	408	252	3	382	1
426	253	395	3	423	1
514	242	428	3	430	1
530	227	449	3	437	1
47	217	534	3	453	1
504	144	560	3	512	1
436	34	425	3	540	1
422	33	106	2	546	1
260	32	232	2	556	1
119	19	264	2	600	1
195	16	427	2	702	1
204	14	455	2	704	1
510	8	549	2	707	1
127	6	7	1	738	1
548	6	8	1	808	1
554	6	11	1	924	1
364	5	53	1	935	1
525	5	84	1		
544	5	99	1		

In this round, four class numbers 424, 425, 808 and 924 missed in the previous round are also included. Another six class numbers 438, 135, 252, 425, 232 and 455 should not be considered, because the patents filed under these numbers are reclassified to

other existing class numbers, which means these six numbers do not continue to represent the agricultural biotechnology field.

In the methodology section, we have specified that our training set is the combination of **TrueABP7600** and **6ClassPatents7600**, which means that the training set and the predictive model are fixed. However, the test set can be modified by selecting patents filed in different class numbers. The scope of the class numbers used in the test set will be consistent with the one in the prediction result. The class numbers appearing in **TrueABP7600** have been updated in Table 4.3.

Table 4.3—34 Class Numbers in the Test Set

MainClass	**Frequency**	**MainClass**	**Frequency**
435	5835	127	6
800	1917	548	6
424	987	554	6
71	580	364	5
536	408	525	5
426	253	544	5
514	242	210	4
530	227	162	3
47	217	395	3
504	144	428	3
436	34	449	3
422	33	534	3
260	32	560	3
119	19	106	2
195	16	264	2
204	14	427	2
510	8	549	2

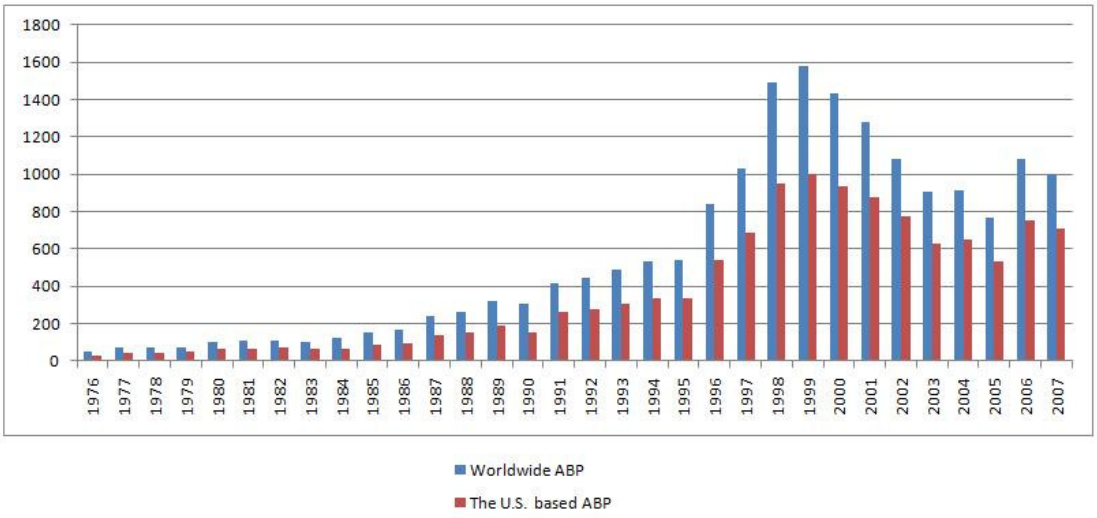

Figure 4.6—The Third Round ABP Development Trend 1976-2007

In this round, referring to the USDA's ABP filtering procedure taking into account the patents with assignees belonging to the 350 agricultural biotechnology firms, we include an additional condition to select patents with assignees appearing in the 11,073 patent list. By adding the patents having the same assignees appearing in the 1976-2000 database into initial selection, we have identified **7,031** agricultural biotechnology patents in this round.

4.4. Fourth Round by Considering Percentage Method for Large Class Numbers and Positive Scores for Small Class Numbers

Referring to the above three rounds, the previous agricultural biotechnology selection procedures might be too conservative by only considering patents with positive prediction scores. Therefore, we question whether the initial selection covers a sufficient range of agricultural biotechnology definition. In this new iteration, not only a lower threshold value is suggested for testing, but also another new selection

approach is explored.

By considering an assignee list as another search criterion in the third round, we have seen an increased ABP number. We are interested in adding another searching category to incorporate patents with certain keywords representing a broader agricultural biotechnology definition. The USDA also notes that certain keywords such as "human", "cancer" or "dye" are useful to exclude non-agricultural related patents under class 435 or the now defunct 935 (Genetic Engineering)[15].

The USDA's major concern is to exclude patents in the category of animal studies used for medical purposes. In order to exclude medical science related subject matter from the agricultural biotechnology definition, we have added the following criteria:

(1) 800/9-12 are excluded because they are under the definition "The nonhuman animal is a model for human disease"[16].
(2) Patents with "human" "cancer" and "dye" in their title and abstract under class 800 and 435 are excluded.
(3) Patents with keywords "polymerase", "amplification", "vaccine" or "vaccination" under class 435 are included.

We temporarily name classes with appearing frequencies more than 30 in 76-00

[15] http://www.ers.usda.gov/data/agbiotechip/filtering.htm
[16] http://www.uspto.gov/web/patents/classification/uspc800/sched800.htm

database “large class numbers” and the remaining “small class numbers.” This standard may be adjusted accordingly to different requirements in the future (Refer to Table 4.4).

In this new approach, within each class, we assume that the proportion of patents being qualified as ABP is as the same in the total patent dataset 1976-2000 and 2001-2007. For example, class 435. The percentage of the overall patents being ABP is 19.50% under class 435 in 1976-2000 patent database, so we assume that there is the same percentage of patents being ABP under class 435 in our 2001-2007 database. By multiplying 19.50% with the quantity of the overall patents under class 435 in 2001-2007 database 17,316, we are able to estimate that about 3,377 ABP can be selected.

Nevertheless, we note that this assumption may be overly strict, as it is possible that a patent class is similar to a product life cycle, which means the ABP percentage may change over time. However, due to the limitations of using a machine learning methodology and the lack of evidence to capture the development trend of each ABP class, we have to simply take the same percentages to approximate ABP according to their prediction scores.

Table 4.4—Large Class Number and Small Class Number

MainClass	Frequency	MainClass	Frequency
435	5835	127	6
800	1917	548	6
424	987	554	6
71	580	364	5
536	408	525	5
426	253	544	5
514	242	210	4
530	227	162	3
47	217	395	3
504	144	428	3
436	34	449	3
422	33	534	3
260	32	560	3
119	19	106	2
195	16	264	2
204	14	427	2
510	8	549	2
	Large Class		
	Small Class		

Table 4.5—Estimated No. of ABP in 01-07 database based on 76-00 percentages

Class Number	Percentage (76-00)	Total no. of patents (01-07)	Expected no. of ABP
800	89.00%	3734	3323
435	19.50%	17316	3377
71	9.50%	208	20
504	7.90%	945	75
47	6.50%	1384	90
530	4.30%	4060	175
536	2.40%	3471	83
424	2.40%	16836	404
426	1.80%	2849	51
436	0.70%	2768	19
514	0.60%	24286	146
422	0.30%	4187	13
260	0.10%	23	0

Besides the above concern, we have also identified some reclassifications in the 34 classes. Hence, we have updated our class list accordingly.

(1). Consideration of the reclassification of Class 935 to Class 435 subclass 440-490

(2). Class 260 has been reclassified into 530-554. Since the total number calculated in class 260 in 76-00 is only 22, the reclassification does not affect the percentages significantly.

(3). 557 patents under Class 71 have been reclassified into Class 504. By considering this change, the number of ABP under Class 504 in 01-07 has been raised to 364. The number of ABP under Class 71 has been reduced to 4.

We have identified the three most important class numbers: 47, 435, and 800. Class 47 representing plant husbandry, was broadly accepted by the USDA in their ABP identification procedure. Their second to last step was to take any patent under class 47 or 935 into their ABP selection list. Class 435 not only contributes about 50% to the 11,037 76-00 ABP dataset, but also is a root class that absorbs various reclassifications from other class numbers. Class 800 can be regarded as the one having the highest percentage to be chosen as ABP from its original raw patent data. The importance of Class 800 can be easily seen by taking the same percentage 89% from its portion in **TotalPatents0107**. The major problem now is to know how to deal with Class 47 and 435, which is how to appropriately reflect their importance. Thus, we have tentatively provided three methods in highlighting them differently.

4.4.1 Method A

The first method we apply is to treat all the large class numbers equally except for class 47. The reason we select all the patents from class 47 is to follow the USDA's selection procedure, in which they incorporate class 47 with a high degree of incorporation. For the remaining small class numbers, we simply select the patents with positive prediction scores.

According to Table 4.5, we obtain the expected number of ABP by multiplying the same percentages in 1976-2000 dataset with the total patent quantity per class. Hence, the potential ABP in **TotalPatents0107** under the large class numbers can be fixed.

The procedure under this method can be summarized as below:

(1). Select the full class 47 (Referring to the filtering procedure the USDA used)

(2). Taking the percentage of patents belonging to ABP within each large class in the 1976-2000 database as a reference, estimate how many ABP can be selected within each large class in 2001-2007 database except for Class 47. As shown in Figure 4.8, the histograms in dark green color indicate the patents being chosen by taking the same percentages borrowed from 1976-2000 patent database.

(3). Choose patents only with positive scores under small class numbers.

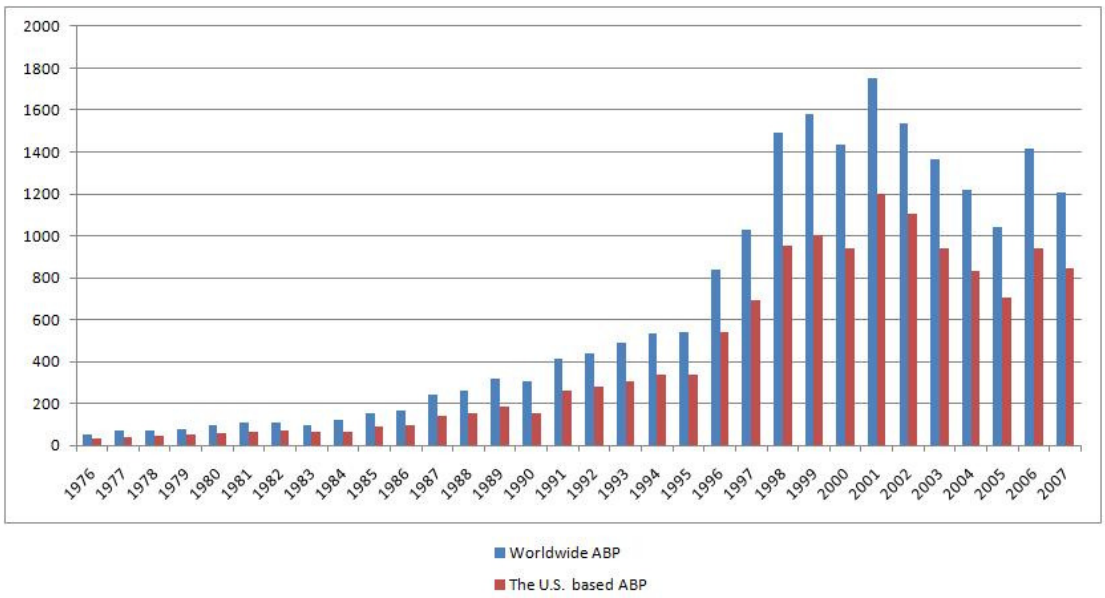

Figure 4.7—The ABP Development Trend 1976-2007 by using Fourth Round Method A

Table 4.6—The Quantity of ABP 2001-2007 by using Fourth Round Method A

Year	2001	2002	2003	2004	2005	2006	2007	Total (2001-2007)
Total ABP	1752	1539	1365	1220	1039	1416	1208	9539
US ABP	1202	1105	939	831	703	943	843	6566

Under method A, we have identified 9,539 worldwide agricultural biotechnology patents and 6,566 the U.S. based agricultural biotechnology patents.

4.4.2 Method B

We notice that some pre-existing class numbers have been entirely or partially reclassified into class 435, such as 438, 135, 425, 455, or 935. In addition, Mr. Jim Hirabayashi from the USPTO has confirmed that part of the class 935 has been reclassified into 435/440-490. Therefore, it may be reasonable to bring in more patents under the modified class 435 because the reclassification makes a greater contribution to the total number of ABP.

Class 435 established its dominating position in 1976-2000 ABP database by contributing to almost 50% of the total ABP. With the multiple reclassifications, we question whether that leading position will be enhanced in 2001-2007 database. Hence, in this method B, under class 435, we select patents with prediction scores greater than the mean value.

<u>The procedure under this method can be summarized as below:</u>

(1). Select the patents under class 435 having prediction scores greater than their average (mean) -0.9186, because some pre-existing class numbers have been entirely or partially reclassified into 435, such as 438, 135, 425, 455 or 935.

(2). Taking the percentage of patents belonging to ABP within each large class in 76-00 database as a reference, estimate how many ABP can be selected within each large class in 01-07 database except for Class 435. (Referring to Table 4.5)

(3). Choose patents only with positive scores under small class numbers.

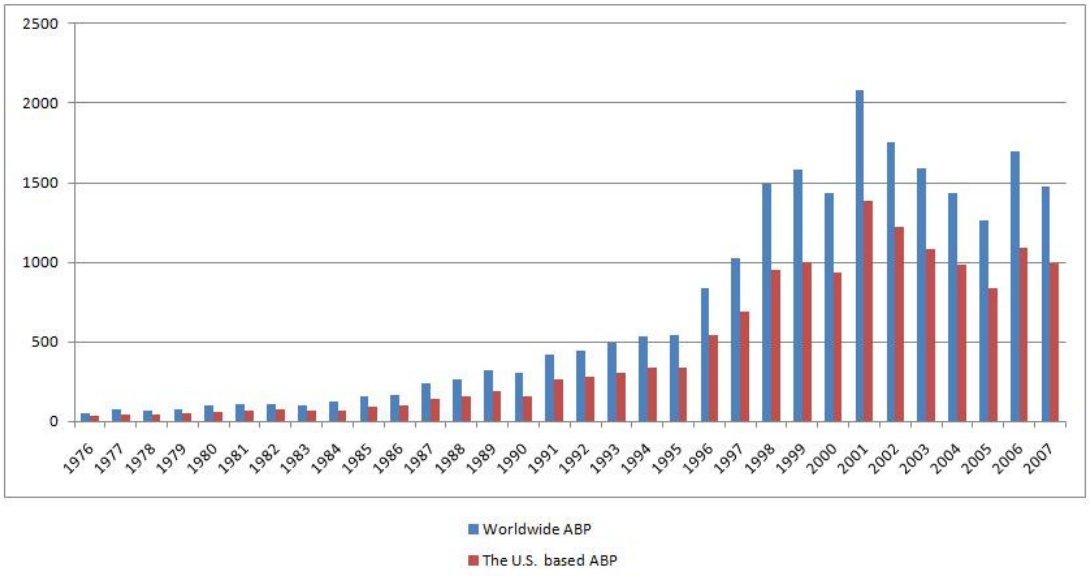

Figure 4.8—The ABP Development Trend 1976-2007 by using Fourth Round Method B

Table 4.7—The Quantity of ABP 2001-2007 by using Fourth Round Method B

Year	2001	2002	2003	2004	2005	2006	2007	Total (2001-2007)
Total ABP	2080	1754	1592	1437	1259	1694	1479	11295
US ABP	1382	1226	1081	984	837	1091	991	7592

Under this method B, we have identified 11,295 worldwide agricultural biotechnology patents and 7,592 the U.S. based agricultural biotechnology patents. Although the Method B gives a prediction result with more impressive growth, we have to agree that setting the mean value for prediction score is tentative but without reference to previous related research work.

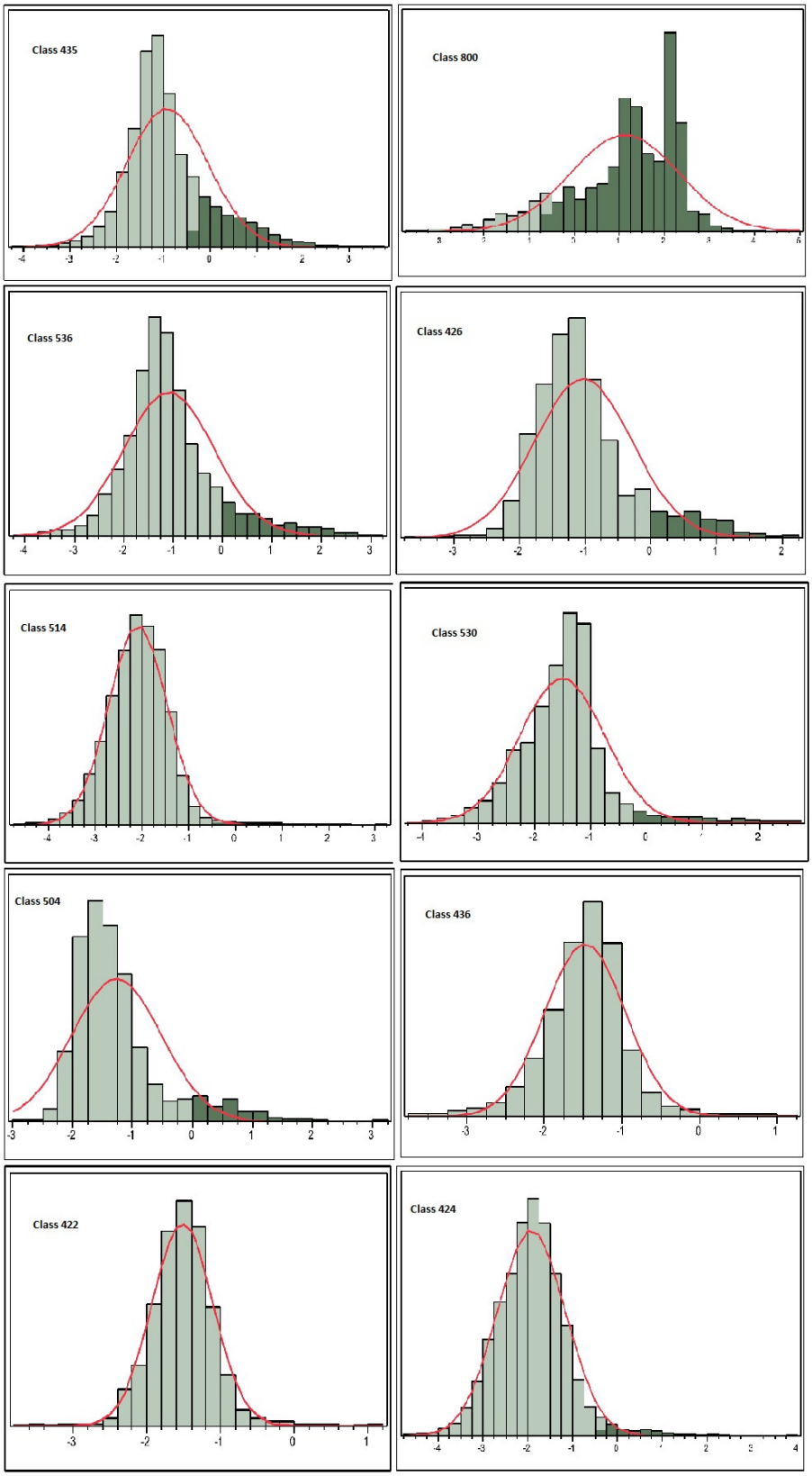

Figure 4.9—Histograms of Patents filed under Major Class Numbers

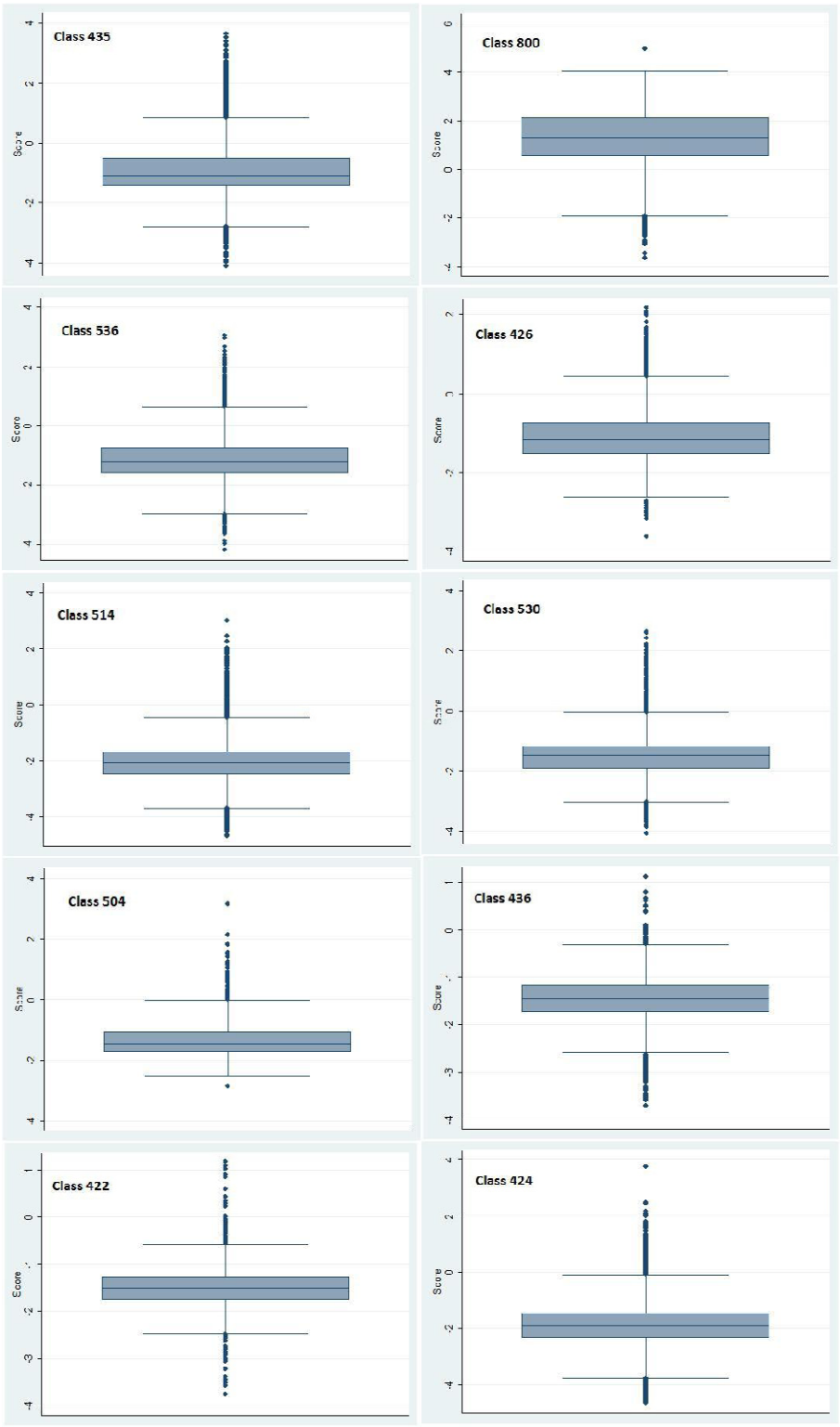

Figure 4.10—Box Graphs of Patents filed under Major Class Numbers

4.4.3 Method C

As mentioned above, we question whether we should consider setting the prediction score threshold value to be the median value of each class rather than zero. It is conventional to set zero to be the threshold value in the SVM machine learning method, but due to our limited sample size of patent candidates from each class, we have to check the statistical distribution of patent score under each class to see the proportions of positive group and negative group. For this purpose, we have constructed box plot graphs and histograms to check the statistical distribution of the patent prediction scores, shown in Figure 4.9.

According to Figure 4.9 and Figure 4.10, in most cases, the class medians are negative, which tells us that less than 50 percent of patents are unlikely to be ABP. Except for class 800, which is the only one having both a positive median and mean, the distribution of other classes are not significantly different from the normal curve (Figure 4.9).

However, lowering the threshold value to either the median or mean lacks supportive evidence as we do not find that either the USDA or other research centers have conducted similar procedures in their ABP identification project. A median threshold value can easily inflate patent quantity by about 40% for most large class numbers. By following this approach, 2001-2007 annual ABP raises significantly from 2001 (Figure 4.11), and this extreme abnormal increase could be a signal to invalidate this

over aggressive approach.

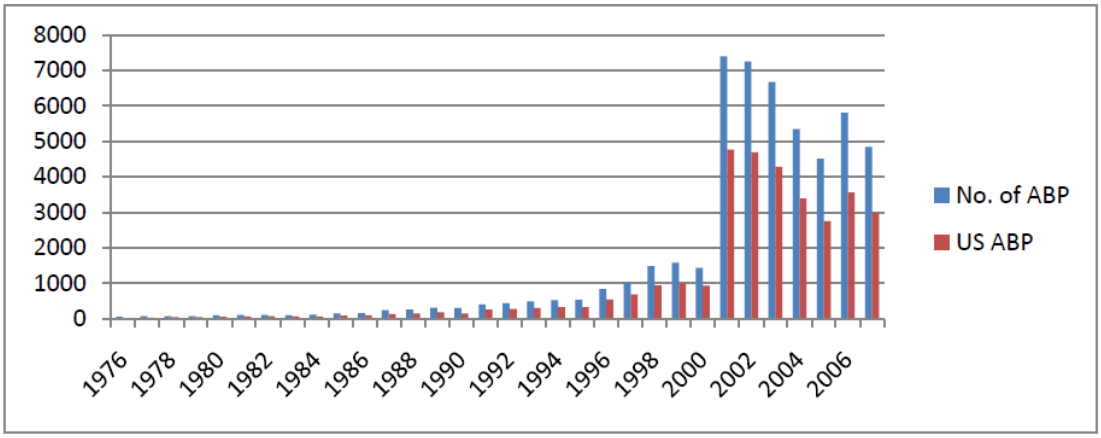

Figure 4.11—The ABP Development Trend 1976-2007 by using Fourth Round Method C

4.4.4 Conclusion

We have decided to choose the identification result by using the method A to be our final ABP dataset for patents issued between 2001 and 2007. As mentioned at the beginning of this section, we have obtained an expected ABP trend by combining both the overall utility patents trend and the expected downward trend derived from the growing industry concentration ratio. Thus, based on this point, an ideal predicted trend should at least not drop substantially compared to the quantity in 2000 and meanwhile rise again from 2006. The result from the Method A is more appropriate to match these two expectations.

Once again, setting the threshold value to be the mean of patent scores can aggressively inflate the ABP quantity about 50%, and there is no relevant previous proof for this inflation, so it is preferable to be more conservative to only take a same

proportion of ABP from Class 435.

Referring to the Table 3.2 in the Methodology section, we calculate precision, recall and accuracy rates in the 10-fold validation experiment. However, in the ABP identification result for patents issued between 2001 and 2007, we are unable to provide a similar result as we do not have an official given true or false values for each patent. We select patents based on ranking their prediction scores, so the selection result is an empirical result. Without given an official true-false results to determine the qualification for ABP, the precision, recall and accuracy rates of patents issued between 2001 and 2007 cannot be calculated.

CHAPTER 5

ECONOMIC ANALYSIS

5.1 Introduction

We have identified a new set of ABP data consisting of patents issued from 2001 to 2007 by using our machine learning methodology. For consistency, we have named the dataset as **TrueABP0107** according to the naming standard in Chapter 3.

The annual agricultural biotechnology patents in **TrueABP0107** have revealed a downward developing trend, as can be seen from 2001 to 2005 in the previous chapter. In this chapter we concentrate on analyzing the characteristics of ABP in several perspectives.

Merger and Acquisition is a popular topic in ABP related research fields, so we are interested in doing case analyses for the top two firms in this industry – DuPont and Monsanto. We divide the ABP dataset of each company into two parts according to the time of the active acquisition activities. The comparison of several ABP characteristics, such as ABP quantity, class composition, and the participation of classes 800 and 435 before and after their M&A activities, is an interesting task in this section.

It is reasonable to differentiate patents into two categories according to the organizational type of their assignees. By receiving different sources in funding their business, firms in the public and private sectors distribute different funding allocations in their research and development sections. Comparison of other aspects in the public and private sectors has been actively conducted by the USDA and other research fellows. In the second subsection of this chapter, we will conduct several comparisons about the ABP quantity, the ABP research productivity, and the ABP class composition under each type.

Apart from the absolute ABP trend, given the statistics of the overall utility patents, we are able to calculate the percentages of the overall utility patents belonging to ABP categories. This relative figure can help reduce the influence of common macroeconomics factors representing a general economic situation such as, GDP, unemployment rate, or inflation index. Therefore, the relative figure can help display a trend of ABP determined only by agricultural technology related factors. Each patent has an application date and a publication date. The statistics of patent quantity vary differently according to which date we choose. In the third subsection of this chapter, we will provide two types of relative figures by selecting different patent dates.

Furthermore, since our ABP quantity is actually an aggregation of agricultural biotechnology patents issued to assignees registered around the world, the component

belonging to foreign countries is worth investigating. Because the quantity and features of patents conceivably evolve with time, it is meaningful to observe these changes to illustrate the position of the United States in contributing to agricultural biotechnology innovations. In addition, we are also interested in knowing the percentages of the U.S. based overall utility patents belonging to ABP categories. We will conduct case analyses for four selected countries: Germany, Japan, Australia, and China. We will also compare the differences of their ABP quantities and class composition.

5.2 Merger and Acquisition

Merger and Acquisition is a common strategy used in corporate restructuring activities by selling, purchasing, or combining companies without creating a new business entity. In the process one company loses its identify and is taken over by another stronger company (Thomas, 2009). In contrast, consolidation is the combination of two separate companies to create a completely new, independent company with a new business identity.

The large amount of M&A activities in the agricultural biotechnology industry in the late 1990s has caused concern about the impact on agricultural biotechnology innovation, as well as on farmers (Brennan *et al.,* 2005). One of the impacts was to increase the industry concentration by having the top firms controlling more market

shares. This might have the effect of causing a less than encouraging attitude in a firm's ABP innovation.

DuPont is currently the world's second largest chemical company, according to its market capitalization, producing mainly plastics and rubber products. In 1997 in order to change its business scope to be more life-science focused, DuPont purchased 20% of Pioneer's shares. At that time Pioneer was the largest seed producer in the U.S. In 1999, DuPont followed up by acquiring the remaining 80% of Pioneer's shares for $7.7 billion. Besides Pioneer, DuPont also purchased Imperial Chemical Industries in 1995, Herberts in 2000, and Liqui-Box Corporation in 2002. However, our interest lies in the investigation of DuPont's relationship with Pioneer only because of our ag-bio research orientation. In other words, we will considerably narrow our research interests on the comparisons of DuPont's several ABP related characteristics before and after its acquisition of Pioneer.

Pioneer Hi-Bred is an important subsidiary under DuPont and a leading producer focusing on hybrid seed production. Monsanto concentrates on genetically engineered (GM) seed invention and, at the same time, is chemical oriented producing herbicide glyphosate.

Since these three firms play important roles in the agricultural biotechnology industry, we are interested in knowing the percentages of their ABP quantities contributing to

the total worldwide ABP quantity.

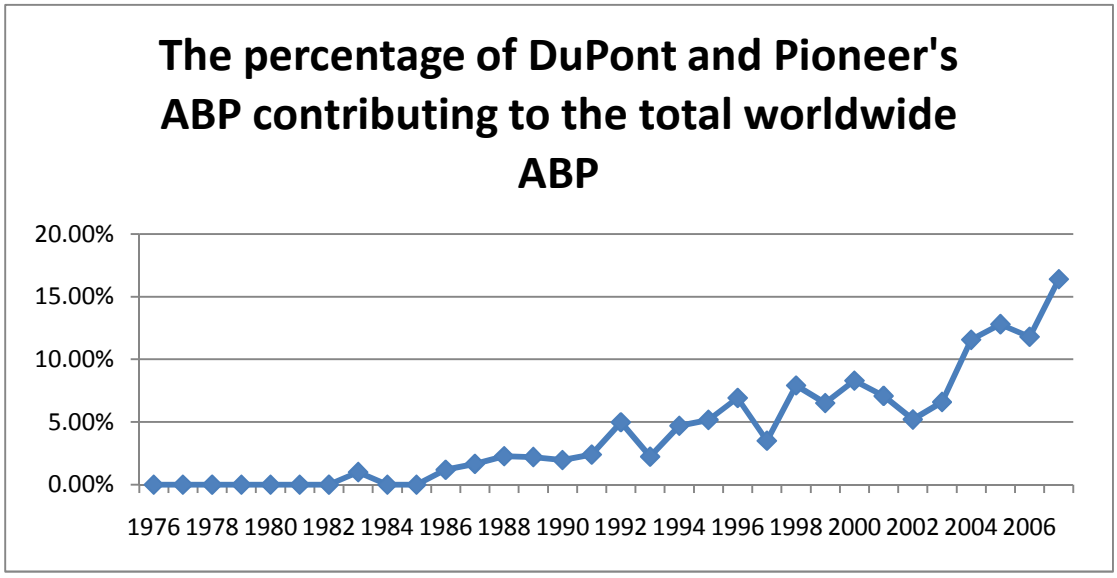

Figure 5.1—The Percentage of DuPont and Pioneer's ABP Contributing to the Total Worldwide ABP

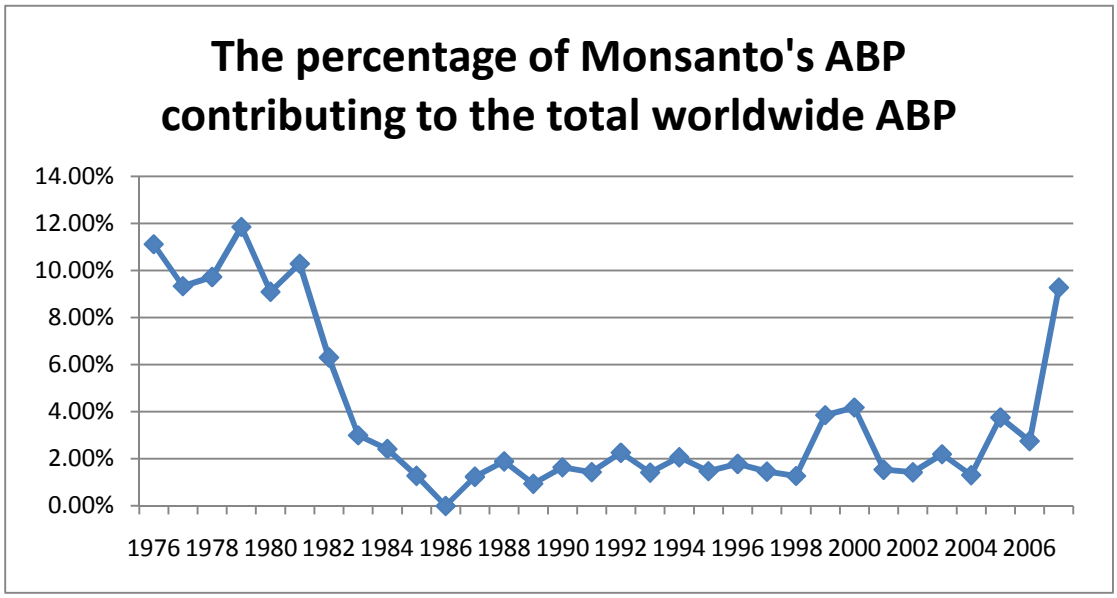

Figure 5.2—The Percentage of Monsanto's ABP Contributing to the Total Worldwide ABP

We can see that the combination percentages of DuPont and Pioneer generally follow an upward trend. In 2007, its combining percentages exceeded 15%. However,

Monsanto's percentage firstly experienced a downward trend from 1976 to 1986, and was followed by a stable period until a short boom in 1999 and 2000. Another new increasing trend started from 2001 and reached a much higher value around 10% in 2007. Monsanto seems to contribute more significantly in the first six years but that is probably due to the smaller total worldwide ABP quantity.

In the late of 1990s, the strategy of DuPont's agricultural biotechnology acquisitions was to concentrate on acquiring one big firm within a short period of time by spending a large amount of acquisition expenditure. In contrast, Monsanto, as a leading producer in genetically engineered (GM) seeds in the United States, acquired several small firms within a relatively longer period. For example, Monsanto purchased Agracetus, Asgrow, Holden's Foundation Seed, Sementes Agroceres (Brazil based), DeKalb, Cargill (International based), and Mahyco (Indian based) from 1996 to 1999 (Freese, 2007). The largest amount spent in its acquisitions is $3.7 billion for DeKalb and the average amount spent for the remaining firms is about $100 million to $1.5 billion in 1998. At this point, we can see that Monsanto, as a big ag-bio firm, expanded its business within the same industry by using a less intensive but steady approach. In contrast, DuPont, as a chemistry oriented big firm, expanded its business to be more life-science focused by using a faster and more intensive approach.

Due to Monsanto's less intensive but steady acquisition activities from 1996 to 1999,

it is not easy to fix a specific acquisition time point by which to conduct the comparison before and after its acquisitions.

To solve this problem, we have to simplify the acquisition information of Monsanto to select a point of time or a period of time to divide its whole ABP database into two parts. In Monsanto's case, we notice that it spent $3.7 billion to purchase DeKalb, $1.4 billion to purchase Cargill, and less significant amount to acquire some other smaller ag-bio firms in 1998. Its total acquisition expenditure in 1998 was at a maximized value compared to other years in the range of 1996 to 1999 (Freese, 2007). Therefore, we narrow our research interests on the comparison of Monsanto's ABP related characteristics before and after its relatively intensive acquisition year of 1998.

One commonly accepted advantage of Merger and Acquisition is to make two corporations work more efficiently, which is regarded as the enhancement of synergies (Hughes, 1989). The reasons to pursue M&A activities may also include gaining more market domination or diversification. Unfortunately, sometimes returns from M&A activities may not meet the expectations of M&A planners. The problems encountered during M&A activities may have serious consequences, such as financial and profitability problems like the shortage of cash due to high expenditure on M&A activities (Henry, 2002).

Some implicit factors, such as the culture difference between two corporations or high

employment turnover rate due to the uncertainty about the future of the new corporation, can also cause serious issues after M&A activities (Appelbaum *et al.,* 2000).

The implicit factors are hard to capture by using data analysis, but the profitability performance can be roughly measured by an important financial ratio Return on Equity (ROE) (Sharma, 2008). ROE is calculated by dividing the net income by the average of stockholders' equity of the most recent two years.

We are interested in investigating the profitability performance of DuPont and Monsanto after their major M&A activities by checking the value of ROE ratio from their historical 10-K reports in the following subsections.

Given the financial conditions of these two companies, we are further interested in knowing their annual ABP quantities and meanwhile checking the class composition before and after their major M&A activities, especially the evolution of class 800 and 435 in the following subsections.

5.2.1 DuPont and Pioneer

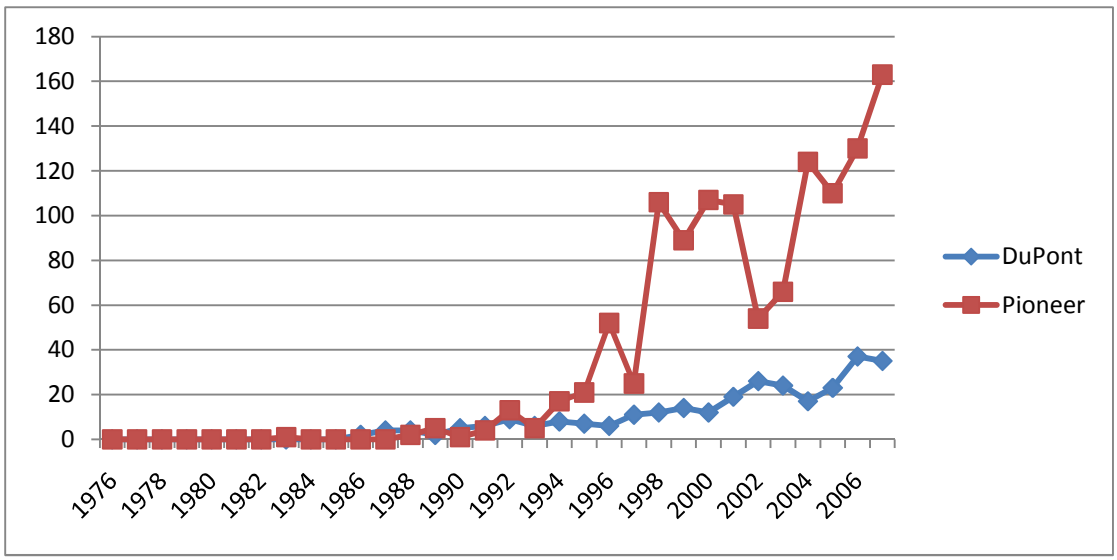

Figure 5.3—ABP Quantity (Grants) of DuPont and Pioneer 1976-2007

The assumption in counting ABP quantity in Figure 5.3 for DuPont is to consider patents issued to DuPont and Pioneer on a worldwide basis. For example, the ABP quantity of DuPont refers to the number of ABP owned by all the DuPont branches in the world.

Prior to 1997 in Figure 5.3, Pioneer was not very productive in owning agricultural biotechnology innovations. However after the purchase of 20% of its shares by DuPont in 1997, Pioneer's ABP quantity reached a much higher level of more than 100 ABP in 1998. After the complete acquisition in 1999, Pioneer's ABP quantity firstly maintained at a high level in 2000 and 2001, but dramatically fell by about 40% in 2002 and 2003.

Through the M&A activities carried out, DuPont successfully expanded its business scope by incorporating more agricultural biotechnology patents. As shown in Figure 5.3, DuPont owned very few agricultural biotechnology patents before 2000 but after its acquisition of Pioneer, a rising trend can be observed.

There could be several reasons for this trend of ABP annual quantity. For example, the drop in 2002 may have been caused by mismanagement in business restructuring procedures, cultural differences between these two corporations, and may be the higher industry concentration, which could have reduced the motivation for innovation. In addition, there could be some other factors that may give contributions to form the above patent trends as well.

The influences of those factors may be correlated to each other or independent. With the limited supporting data in our thesis research, it is difficult to accurately conclude what the exact real factors were that caused the ABP quantity trends of DuPont and Pioneer.

However, it can be meaningful to check DuPont's profitability performance before and after its acquisition of Pioneer to see whether DuPont financially managed this acquisition successfully. Return on Equity (ROE) is defined as the ratio of net income divided by the average of stockholders' equity of the most recent two years.

Even though ROE is not a perfect metric to evaluate a firm's profitability performance, as its simple calculation method may easily involve accounting manipulation (Dyckman *et.al,* 2011), the result in Figure 5.4 is still able to briefly tell that DuPont experienced some problems in its financial performance during the subsequent three years after its full acquisition of Pioneer. From 2003, DuPont started to become profitable and to maintain a relatively increasing profit level.

As shown in Figure 5.4 after the acquisition of Pioneer in 1999, DuPont's ROE ratio started to drop but was followed by an increase in 2001. The value of ROE even became negative in 2002. After that the value rose from 2003 to 2006 with impressive increment annually.

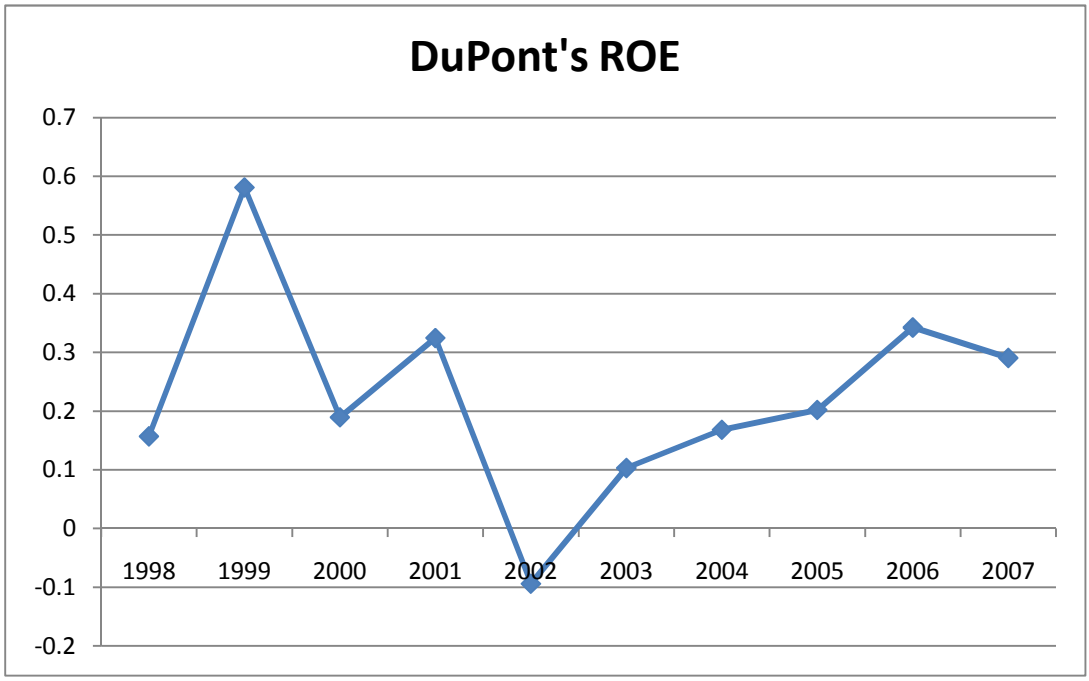

Figure 5.4—DuPont's ROE 1999-2007

In this thesis we define a patent's time to be its approval time which is the time when the patent is granted to its applicant. A patent also has its application time which is the time when this patent is applied for through the USPTO. There is a time lag between a patent's application and its approval, which means patent applicants need to wait for a certain amount of time to get their patent approvals. By defining a patent's time to be its application time, we will have a different trend of ABP quantity submitted to the USPTO every year. Therefore, apart from the financial performance, due to the existing time lag, it is also meaningful to compare the trends of both patent application and grant in order to analyze the impact of the former on the latter. .

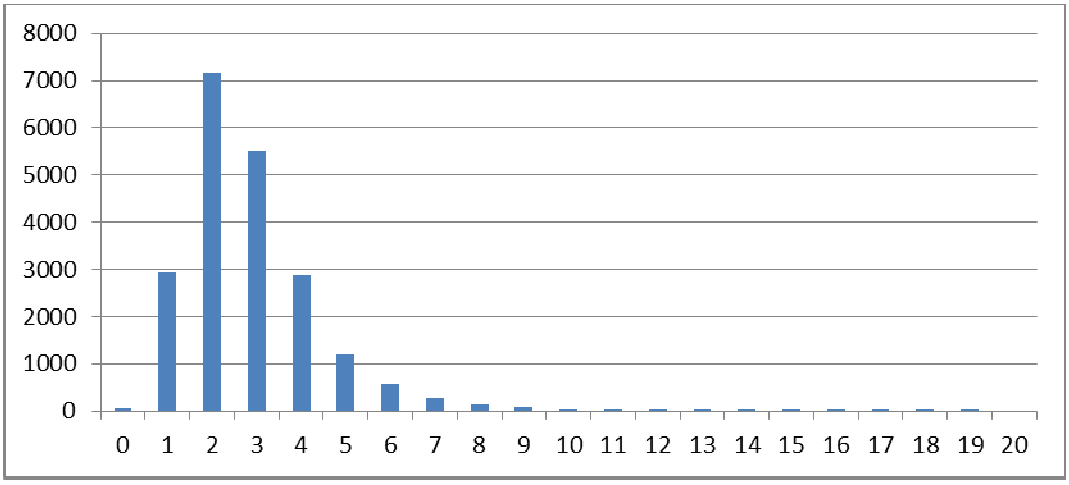

Figure 5.5—The Distribution of the Time between Patent Application and Approval
Source: Calculation done by using ABP data in TrueABP7600 and TrueABP0107

However, there is a limitation in counting ABP applications in our identified ABP dataset because of this time lag problem. In most cases the waiting time is 2 years according to the statistical result calculated by using the ABP data in both the datasets of **TrueABP7600** and **TrueABP0107** (shown in Figure 5.5).

By calculating the waiting time in a weighted average method, we can see that normally patent applicants need to wait for 2.85 $\approx$3 years to receive their approvals. With this method of calculation, it is not fair to use the very recent application quantities due to this truncation problem, because we only target patents issued no later than 2007. Patents may need longer time, such as more than 3 years, to be approved. For example, a patent may be applied for in 2005 and issued in 2008. Since we only select patents issued no later than 2007, the patent issued in 2008 will be out of consideration even if it was applied for in 2005. At this point, the application quantities in more recent boundary years will be deflated. This deflation can be viewed in Figure 5.5 which is about the ABP application quantities of DuPont and Pioneer. We can see that the patent quantity substantially drops within the most recent three years (2003-2006). Each firm's value of ABP application is zero in 2007 so that we do not include it in this figure. This huge decline is reasonable as patents applied for within the most recent three years may need longer time to be approved. Since we cut off the patent dataset by only collecting patents issued no later than 2007, patents having longer waiting time will be out of consideration.

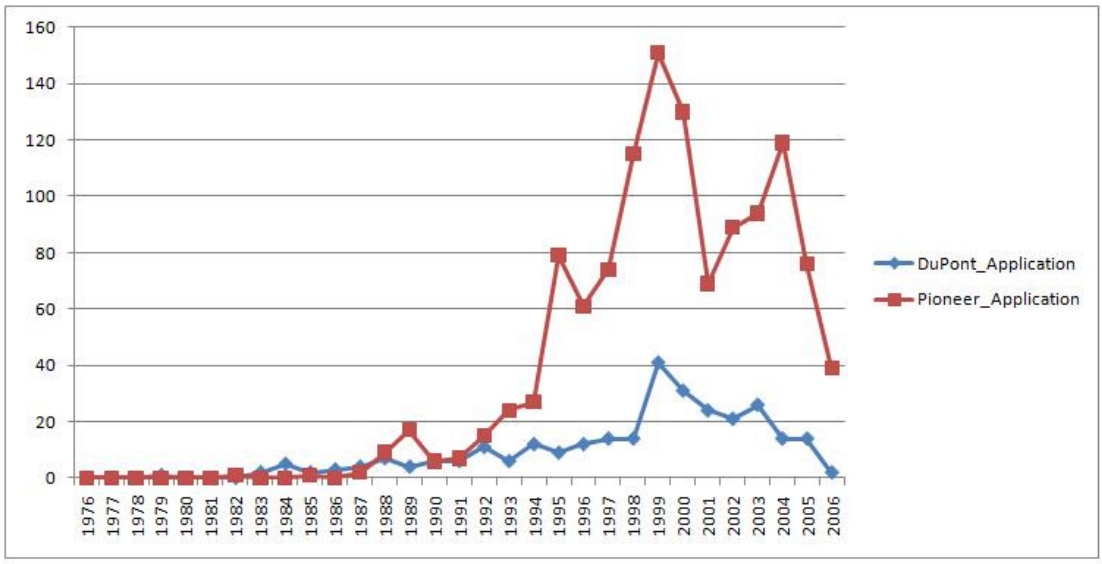

Figure 5.6—ABP Quantity (Applications) of DuPont and Pioneer 1976-2006

In order to be more accurate in the following Figure 5.6 comparing the trends of ABP application and grant quantities, we only include the ABP application data up to 2000 and the ABP grant data up to 2007. The 2.8≈3 years time lag is an average value, which is calculated by using the overall ABP data in both TrueABP7600 and TrueABP0107 datasets. Therefore in these smaller datasets of DuPont and Pioneer data only, it may not be accurate to apply this time lag standard. It is conservative but more accurate to discard the ABP application data in the range of 2001-2007, so that the most recent application data in 1976-2000 range can have a seven years waiting buffer.

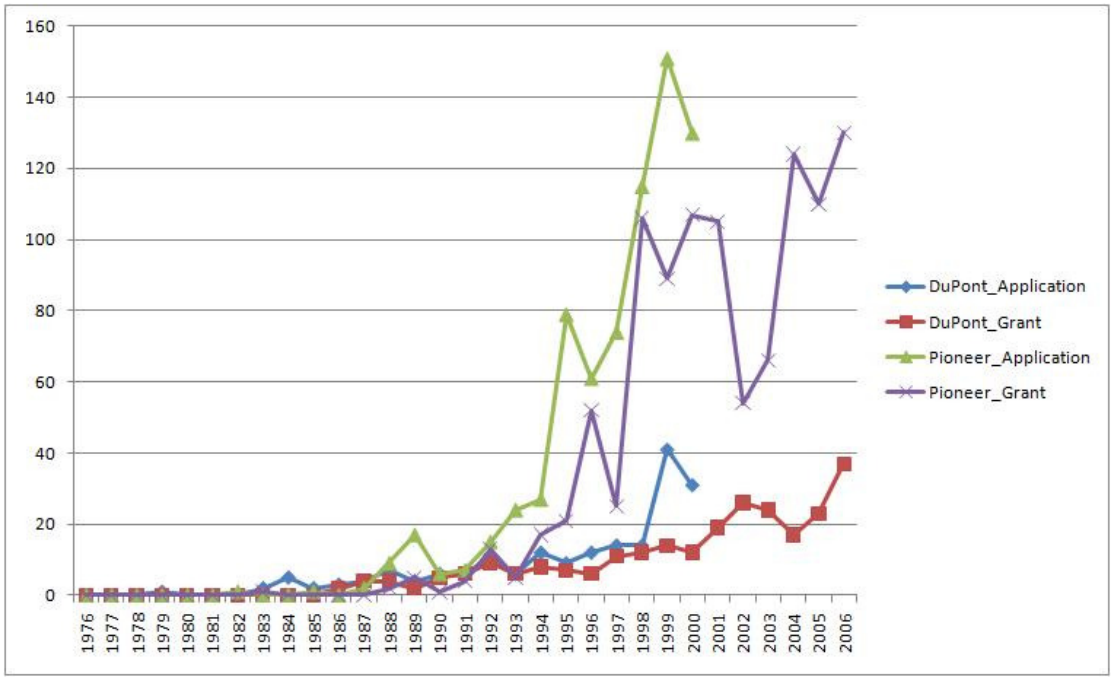

Figure 5.7—Comparision of ABP Application and Grant Quantities of DuPont and Pioneer 1976-2006

In Figure 5.7 Pioneer's trend of the ABP application quantity generally follows a similar shape with that of the ABP grant quantity by having about 1-3 years time lag from 1990 to 1998 in the ABP grant trend. After 1998 in the ABP grant trend, the shapes of those two trends seem to become too irregular to be compared. For DuPont, the similar shape of the ABP application and grant quantities seems to roughly result a three years time lag. For example, the highest value in 1999 on the application trend and the regional highest value in 2002 on the grant trend (this is not a complete sentence). Basically this figure depicts that the quantity of ABP application has conceivable impact on the future quantity of ABP grant, but it may not be a very decisive factor.

Classes 800 and 435 are regarded as the most representative class numbers for

agricultural biotechnology definition, which are selected as an important searching criterion for the ABP identification work in the research papers of Barham and Foltz (2002). Class 800 is defined as "multicellular living organisms and unmodified parts thereof and related processes"[23]. It mainly involves transgenic and seedling methods, and therefore, can be regarded as the most relevant class according to the business scopes of Pioneer and Monsanto. Because class 435 has a bio-chemistry definition of "chemistry: molecular biology and microbiology", we have added class 435 into consideration as DuPont is also a company with chemical orientation.

We have provided a figure of the ABP quantity filed under class 800, 435, and the combination of these two belonging to DuPont excluding Pioneer (shown in Figure 5.8). We can see that the trend of the class 800-435 combination is approximately the total of the ABP trend belonging to DuPont, which proves that these two classes are the core classes in DuPont's ABP database. Figure 5.8 clearly shows that the number of ABP under class 435 was in a dominant role before 2002. The number of ABP under class 800 exceeded the number under class 435 from 2002.

[23] http://www.uspto.gov/web/patents/classification/uspc800/sched800.htm

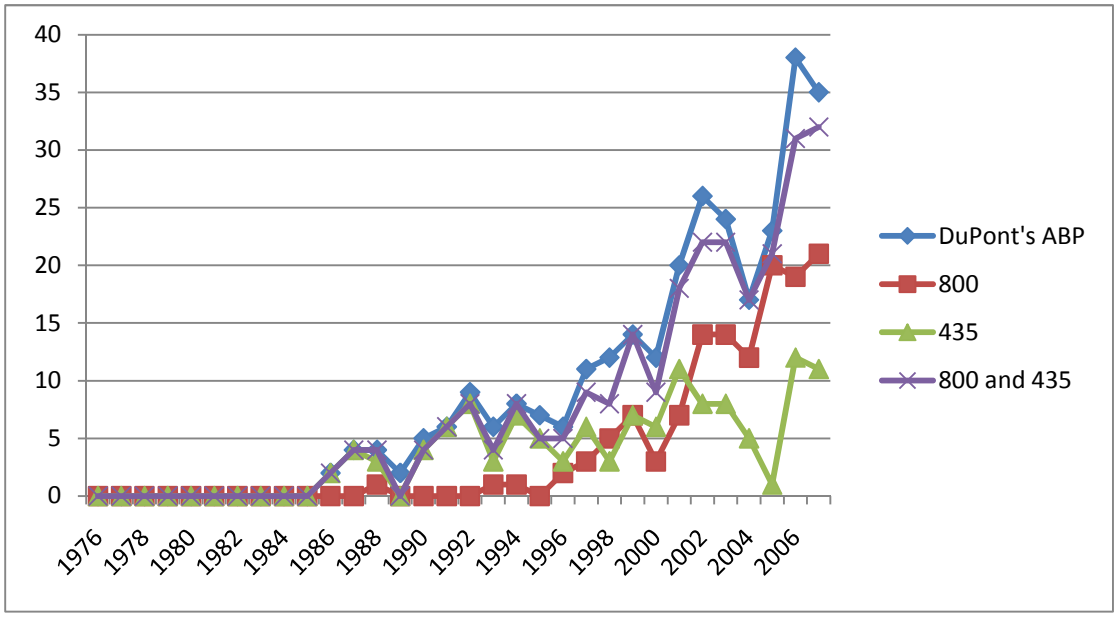

Figure 5.8—ABP Quantity of DuPont (Overall, Class 800 and 435)

Generally, Figure 5.8 shows an upward trend of DuPont's ABP quantity. In this figure, we are able to see a more specific trend change of DuPont. It seems clear that class 800 has replaced class 435 to become the top class category held by DuPont since 2002. As two core representative class categories of ABP definition, class 800 is more biology oriented but class 435 is more bio-chemistry oriented. After the full acquisition of Pioneer, we can see that DuPont's chemical related portion of innovation has been reduced.

Besides class 800 and 435, we are also interested in knowing other class composition changes pre- and post-acquisition of Pioneer in 1999. We have divided the whole DuPont's ABP dataset into two separate subsets according to a turning point of time at March 15, 1999[24], which is the date when DuPont and Pioneer signed the acquisition agreement. As shown in Table 5.1, class 800 and 435 once again have been proved to

[24] From DuPont's 10-K report filed on March 19, 1999

be the core classes by holding absolute dominant percentages among all the class numbers. The comparison of the class composition pre- and post-acquisition shows a consistent result of an increasing trend of class 800 after the acquisition. The percentage of class 435 has been reduced by half during the post-acquisition period. In contrast, the percentage of class 800 has been increased by more than 2.5 times compared to the percentage during the pre-acquisition period.

Table 5.1—The Comparison of the Class Composition of DuPont during periods pre- and post-acquisition of Pioneer

Pre-acquisition			**Post-acquisition**		
Class	**ABP Quantity**	**% Total**	**Class**	**ABP Quantity**	**% Total**
435	55	66.27%	**800**	117	56.25%
800	13	15.66%	**435**	68	32.69%
536	6	7.23%	**536**	7	3.37%
47	5	6.02%	**47**	6	2.88%
8	1	1.20%	**530**	4	1.92%
71	1	1.20%	**424**	2	0.96%
204	1	1.20%	**264**	1	0.48%
530	1	1.20%	**426**	1	0.48%
Total	83		**504**	1	0.48%
			554	1	0.48%
			Total	208	

In the case of Pioneer, Figure 5.9 depicts that the trends of the overall Pioneer's ABP quantity and the ABP quantity under class 800 and the 800-435 combination do not deviate very far. This helps verify that class 800 holds an absolute leading position among all the classes.

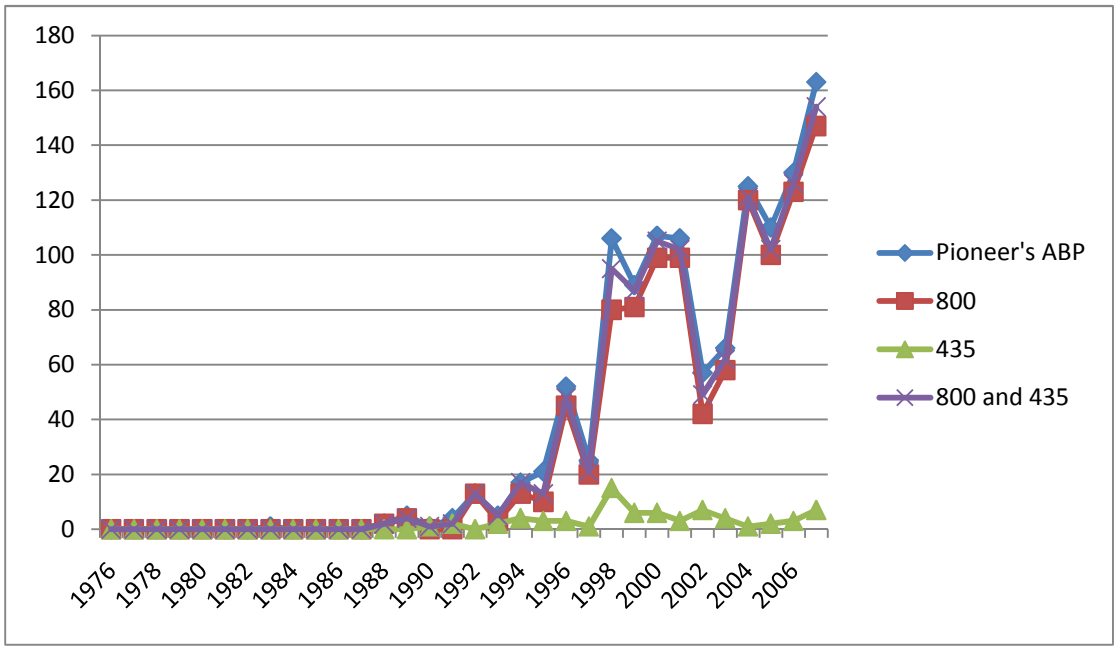

Figure 5.9—ABP quantity of Pioneer (Overall, Class 800 and 435)

Table 5.2—The Comparison of the Class Composition of Pioneer during periods pre- and post-acquisition by DuPont

Pre-acquisition			**Post-acquisition**		
Class	**ABP Quantity**	**% Total**	**Class**	**ABP Quantity**	**% Total**
800	205	76.49%	**800**	855	91.25%
435	32	11.94%	**435**	38	4.06%
536	10	3.73%	**536**	20	2.13%
47	6	2.24%	**530**	14	1.49%
424	4	1.49%	**424**	4	0.43%
530	4	1.49%	**426**	2	0.21%
514	3	1.12%	**514**	2	0.21%
426	2	0.75%	**47**	1	0.11%
504	1	0.37%	**554**	1	0.11%
554	1	0.37%	**Total**	937	
Total	268				

We adopt the turning point of time as March 15, 1999 as well and divide Pioneer's ABP dataset into two parts, before and after the acquisition by DuPont. Before the acquisition, class 800 was the top class contributing more than 75% among all the

class numbers belonging to Pioneer. After the acquisition, the percentage of class 800 rose from 76.49% to 91.63%, and the percentage of class 435 reduced from 11.94% to 4.08%.

In both cases of DuPont and Pioneer, the contribution of class 800 among all the class numbers has been increased after the acquisition. On the contrary, the contribution of class 435 has been reduced after the acquisition.

5.2.2 Monsanto

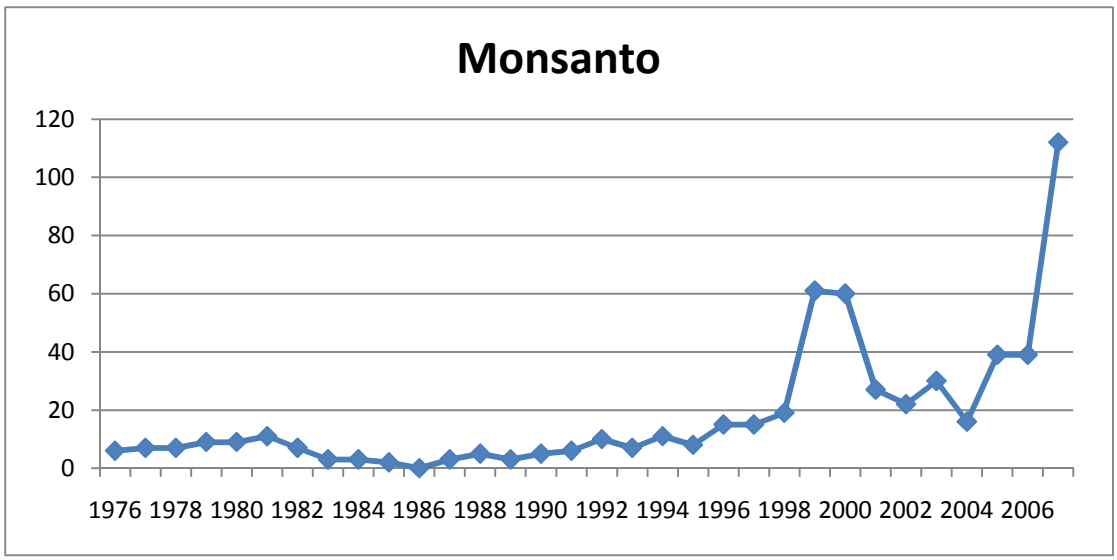

Figure 5.10—ABP Quantity of Monsanto 1976-2007

The assumption for calculating the ABP quantity of Monsanto is the same as the one used for DuPont. The number of ABP counted was based on all the Monsanto branches in the world.

Figure 5.10 describes a developing trend of the ABP quantity of Monsanto. Clearly, we can see that the ABP quantity increased to a much higher value in 1999 right after its largest amount acquisition expenditure in 1998 and remained a high value in 2000. It followed a general declining trend from 2001 to 2004, but rose again from 2005, and it reached its peak value in 2007.

Compared to the ABP quantity level in 1999 and 2000, the subsequent quantities were considerably smaller. This backward trend up to 2004 is likely due to several common

issues after M&A activities. Besides the possible post-merger problems indicated in DuPont's case, Kroon, Noorderhaven and Leufkens (2009) also analyze some integration difficulties of employee factors in the perspectives of organizational culture and identities. Mismanagement in human resources can also cause failures after M&A activities.

However, M&A is only a subsection under Chapter 5 in this thesis. With the limited supporting data and other research resources, we cannot give a deeper explanation of the most direct reason for the ABP trend of Monsanto.

In 2007, Monsanto's ABP had risen significantly to a peak of 112. This was consistent with the time when DuPont reached its peak value. The new peak levels can tell that these top two firms might have finished adjusting to the changes from M&A and returned to a relatively stable stage.

Nevertheless, we are interested in checking Monsanto's profitability performance to see whether it financially managed the acquisition smoothly. ROE is an important profitability ratio that involves accounting information from both income statement and balance sheet, although its simple calculation method may also bring in a certain amount of accounting manipulation.

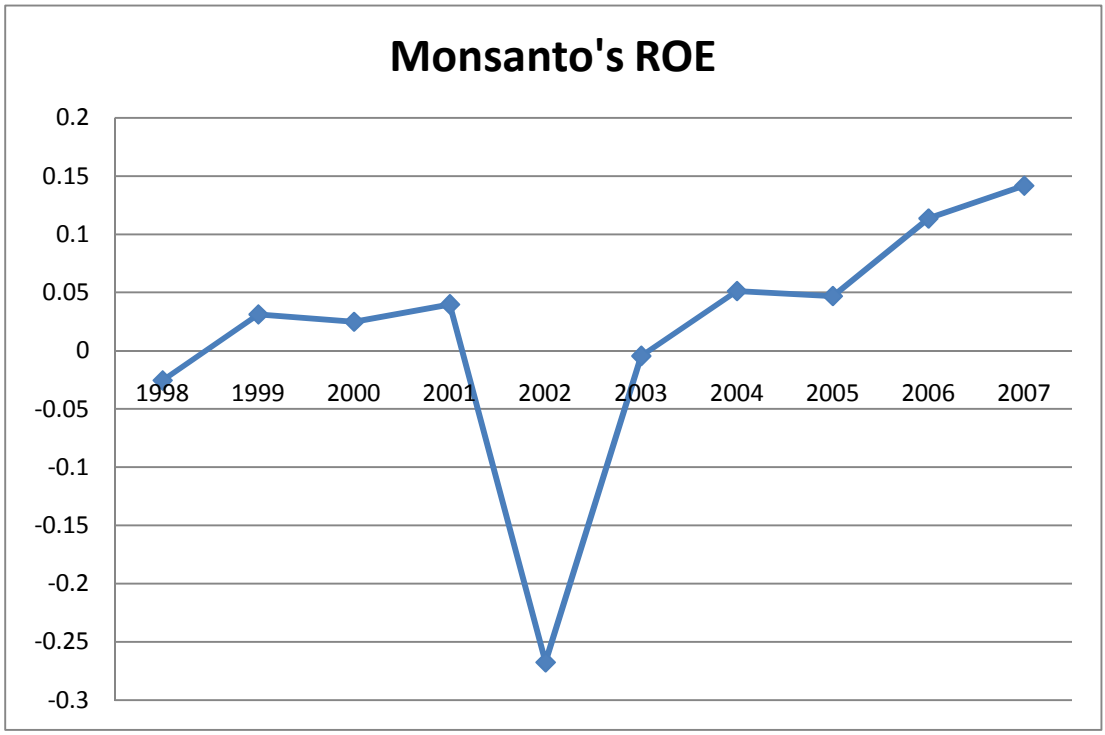

Figure 5.11 Monsanto's ROE 1998-2007

In 1998, Monsanto had the largest expenditure in acquisition. Within the period of 1996 to 1999, we can see that its ROE had a negative value. The high expenditure in that year may be the result of a negative net income.

After that, its ROE started to grow and become positive from 1999 to 2001. Given the information that Monsanto focused on purchasing small ag-bio firms from 1996 to 1999, its ROE maintained at a relatively stable level within two years after its four years lasting active acquisitions. After that, its ROE experienced a significant drop by having a negative value less than -0.25 in 2002.

Although its ROE value was still below zero in 2003, its profitability performance started to grow in a right direction from then on. Monsanto also experienced a

financial shortage four years after its major M&A activities in 1998. It is possible that the shortage was caused by the accumulative effect from its four year lasting acquisitions from 1996 to 1999. However with limited supporting data, we cannot confirm this causal relationship.

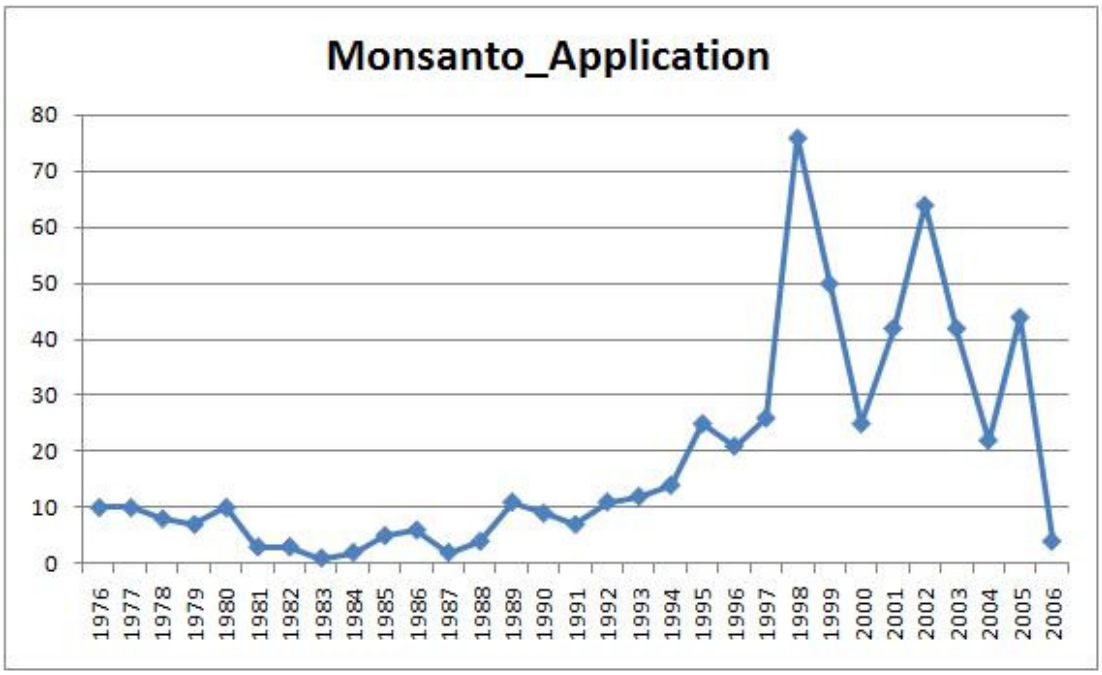

Figure 5.12—ABP Application Quantity of Monsanto (1976-2006)

Figure 5.12 is about the trend of Monsanto's ABP application data. We can see the abnormal low values within the last three years. The reason is due to the same inevitable truncation problem as in our 2001-2007 ABP dataset. By showing the application trend together with the grant trend in Figure 5.13, these two trends roughly follow a similar shape by having a 1-2 years time lag. This can reflect that a large amount of ABP applications will possibly lead to a large amount of ABP grants. However just as indicated in DuPont's case, the application quantity cannot be a

decisive factor to cause an exact same quantity change in the future grant trend.

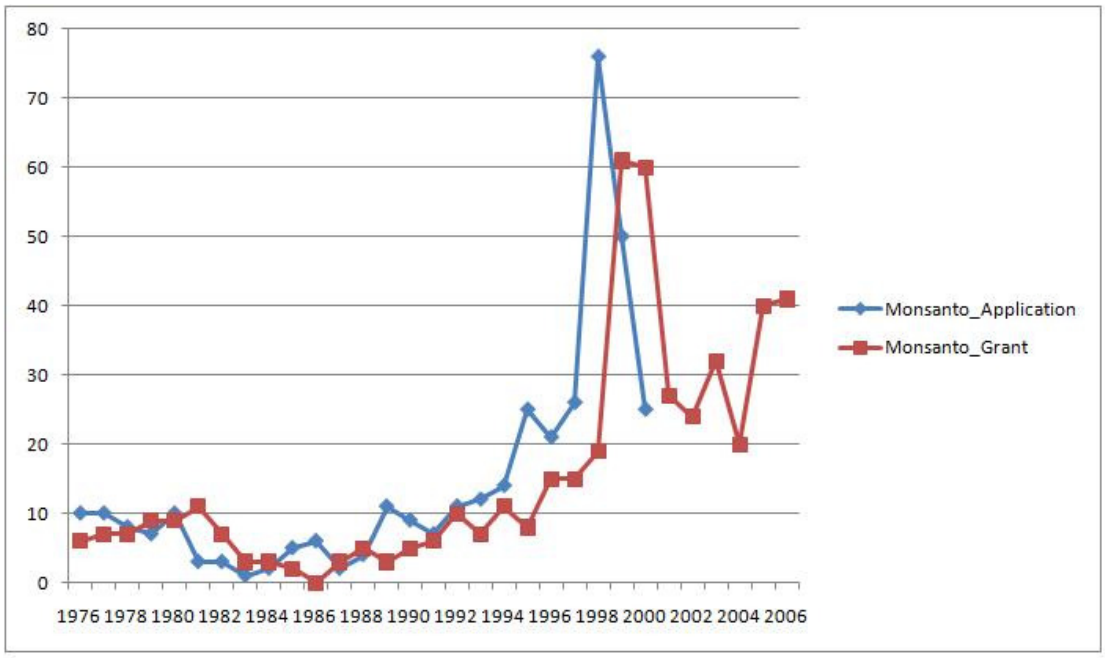

Figure 5.13—ABP Application and Grant Quantities of Monsanto (1976-2006)

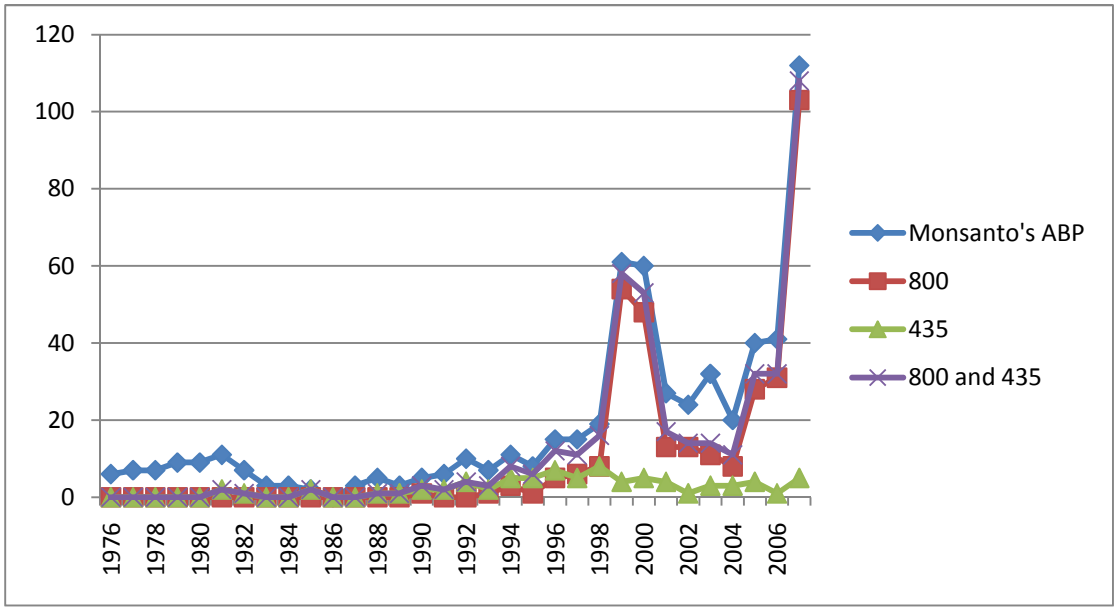

Figure 5.14—ABP quantity of Monsanto (Overall, Class 800 and 435)

Figure 5.14 proves again that class 800 is a representative class for Monsanto as well.

The distribution of Monsanto's ABP quantity under class 800 and the combination of

800 and 435 are roughly consistent with the distribution of its overall quantity.

Regarding the distribution shape of Figure 5.8, 5.9 and 5.14, we can see that Pioneer, as a typical ag-bio firm, has the top three ABP quantity lines getting close to each other. Monsanto's three lines also do not deviate far from each other and we can see that the participation of class 435 is relatively trivial in this case. Conversely, DuPont, with its main chemistry concentration, displays that the top three ABP quantity lines are relatively far from each other, which indicates a higher degree of contribution from class 435.

Table 5.3—The Comparison of the Class Composition of Monsanto during periods pre and pro the Acquisitions of Multiple Small Firms

Pre Acquisitions			**After Acquisitions**		
Class	**ABP Quantity**	**% Total**	**Class**	**ABP Quantity**	**% Total**
71	57	33.33%	**800**	309	74.10%
435	47	27.49%	**435**	30	7.19%
800	25	14.62%	**536**	19	4.56%
530	11	6.43%	**530**	16	3.84%
514	8	4.68%	**514**	15	3.60%
536	7	4.09%	**504**	14	3.36%
424	6	3.51%	**424**	10	2.40%
260	3	1.75%	**47**	2	0.48%
548	3	1.75%	**426**	2	0.48%
47	1	0.58%	**Total**	417	
195	1	0.58%			
438	1	0.58%			
560	1	0.58%			
Total	171				

We divide the whole Monsanto's ABP dataset into two parts: 1976-1998 and 1999-2007. We treat the year 1998 with intensive acquisitions in the first category.

DuPont purchased the big ag-bio firm Pioneer so it is easier to pinpoint the exact turning point in time. Yet in this case, Monsanto acquired several small ag-bio firms from 1996 to 1999. It seems ambiguous to define the year 1998 in either category, but we decide to put it in the pre-acquisitions category.

The percentage of class 800's participation increased in the post-acquisition period from 14.62% to 74.10%. The percentage of class 435's participation decreased in the post-acquisition period from 27.49% to 7.19%. Class 71 served as the top class in the pre-acquisition period, but disappeared in the post-acquisition period due to its paritical reclassification. Considering the results from Table 5.1 and 5.2, the changes in class composition of these three firms display a similar pattern, which is the rise of class 800's participation but a decline of class 435's participation after their M&A activities.

5.2.3 Conclusion

The top two firms in the agricultural biotechnology industry, DuPont and Monsanto, experienced similar but slightly different reactions to their major M&A activities in 1999 and 1998. Both their ABP quantities rose from the year of acquisitions but dropped in a few years after the M&A activities and reached their peak values in 2007. According to their ROE values, they also experienced similar financial shortage after their M&A activities and became profitable shortly thereafter. We also compared the

trend of ABP application quantity with that of ABP grant quantity to give a clear view of the impact from the former on the latter.

In addition, we have confirmed that class 800 is a dominated class in the patent data of these two firms during the post-acquisition period. In both cases, the contribution of class 800 increased after M&A activities and class 435 declined during the post-M&A period.

5.3 Private Sector vs. Public Sector

As defined in the literature review section, an assignee relying on government based public funding is treated as a public type and those depending on their own capital fund or financing through stock issuance are treated as a private type. At the macro-level, we refer to them as the public sector and the private sector.

The public sector includes universities, states or government-owned research institutions and organizations. Universities are an important component within the public sector. The private sector incorporates all independent business entities on their own financing source, such as DuPont and Monsanto.

5.3.1 The Comparison of the Public Sector and the Private Sector

Besides the research about the public and private sectors described in the literature

review section, there is some other work concentrating on the comparison of their research ability in several other forms.

The USDA has summarized the statistics about the percentages of the public and private agricultural research expenses of agricultural GDP (Fuglie and Heisey, 2007), and concluded that the growth rate of the private sector exceeded that of the public sector in the early 1980s (Figure 5.15).

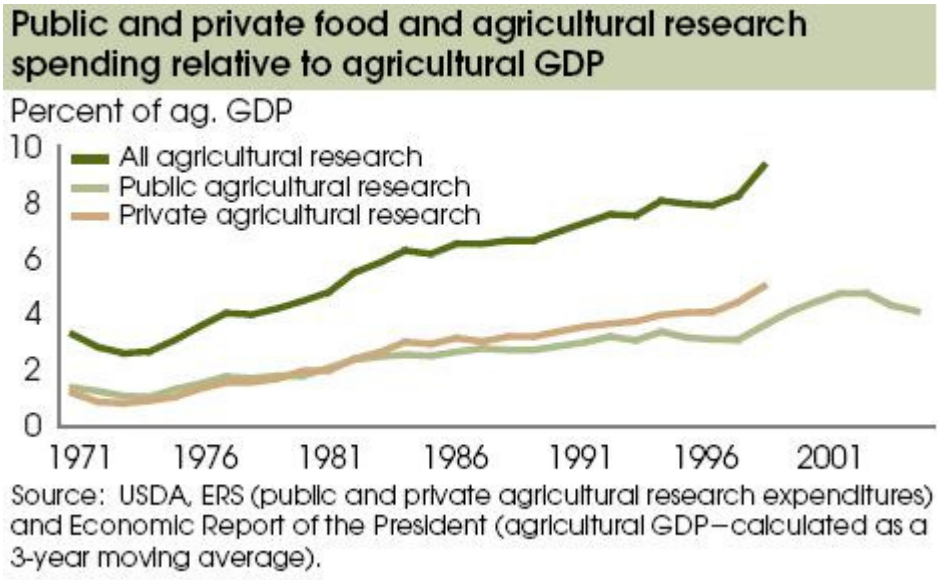

Figure 5.15—Public and Private Agricultural Research Expenditure vs. Agricultural GDP
Source: Keith O. Fuglie and Paul W. Heisey, "Economic Returns to Public Agricultural Research", *ECONOMIC BRIEF* NUMBER 10 (2007): pp.3

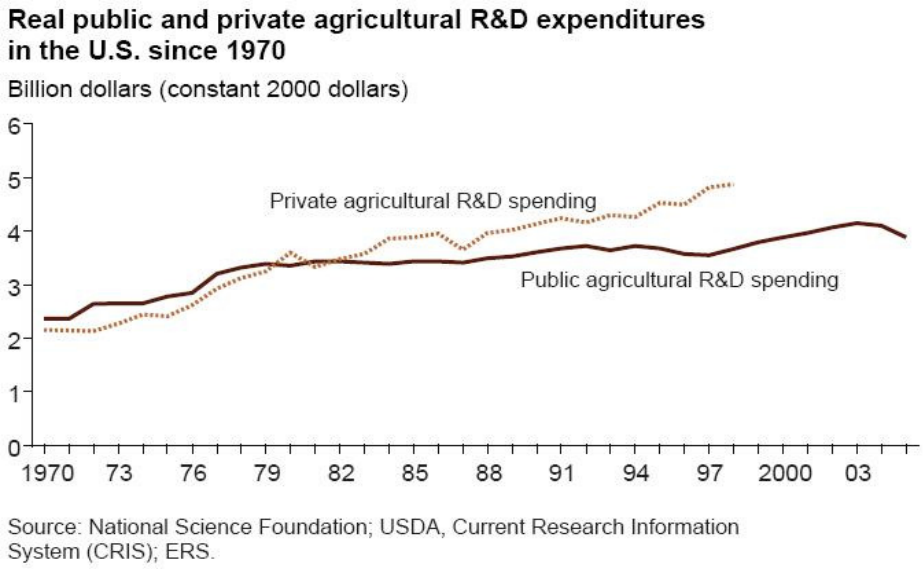

Figure 5.16—Real Public and Private Agricultural R&D Expenditures in the U.S. since 1970
Source: David Schimmelpfenning and Paul Heisey, "U.S. Public Agricultural Research Changes in Funding Sources and Shifts in Emphasis, 1980-2005", *Economic Information Bulletin* Number 45 (2009): pp.1

Schimmelpfenning and Heisey (2009) compared the R&D expenditures of the public and private sectors since 1970. The developing trends of these two public-private variables reveal a similar shape as the one shown in Figure 5.15. The private R&D expenditure surpassed that of the public sector in the early 1980s and started to grow rapidly from then on (shown in Figure 5.16).

It seems that the research on the comparison of the public and private sectors is a popular topic in the agricultural biotechnology field. There are various aspects of this comparison that can be explored. In general, the public sector conducts basic research primarily regarding new topics and new areas that have not been explored so much. The new research requires a great amount of effort and advanced facilities, which usually costs a great deal of money in research funding. On the other hand, the

primary goal of most private sector companies is to maximize business profits (Atkinson *et al.,* 2003). It may be the case that most research in the private sector is the application or derivative of the basic research done by the public sector. The private sector possibly focuses more on the relatively mature research which is less risky and gives more return.

In this thesis, we focus on the comparison of ABP quantity from the public and private sectors to see whether the shapes of the two trends are consistent with the ones in Figure 5.16. Manually checking each patent's assignee name is a very tedious task. Hence, we have decided to use a keyword searching method to determine the organizational type of each patent's assignee. We define an assignee containing the keywords "university", "organization", "national", "United States", "college", "office", "foundation", "research" and "center" as public type entities and the remaining as private type entities. By applying this method, we automatically give a higher consideration to patents with private type assignees. Although this imperfect method may unavoidably inflate the ABP number for the private sector, we still adopt this limitation.

Figure 5.17 summarizes our results about the comparison of the ABP quantity in each sector. ABP quantity in the private sector was always larger than the number in the public sector. The gap between them gradually becomes wider. The public type trend is relatively flat compared to the private one, and the shape of the private one within

the range from 2001 to 2007 is analogous to our overall ABP trend predicted from 2001 to 2007.

As mentioned in Chapter 2, we are aware of the limitations of our analysis of simply counting the number of patents. Simply counting the number of patents does show that the private sector has a larger number of ABP.

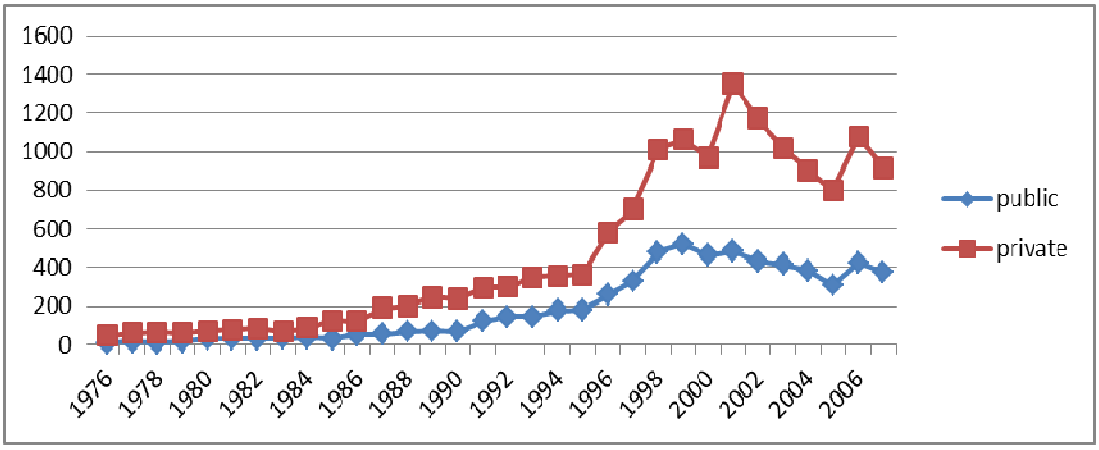

Figure 5.17—ABP of Public Sector and Private Sector 1976-2007
Source: ABP issued between 2001 and 2007 identified by using Fourth Round Method A in this Thesis

It is also worthwhile to check the research productivity which is defined as the number of ABP per million dollars spent in either public or private agricultural R&D expenses (details are in the Appendix B)[25]. The source of the data was developed by the USDA by collecting the public sector agricultural research funding data from 1976 to 2008 and that of the private sector from 1970 to 1998.

Taking inflation into consideration, the USDA developed two formats of the public

[25] http://www.ers.usda.gov/Data/AgResearchFunding/

and private agricultural R&D funding data: one in nominal dollars and the other one in 2001 dollars. The USDA does not give a specific definition of the scope of the term "agriculture" along with the dataset. It is highly possible that the scope of the term "agriculture" here is wider than the definition of our more specific research focus "agricultural biotechnology". Without further detailed information, we have to assume that the agricultural R&D funding data is approximately equivalent to the R&D funding data in agricultural biotechnology fields.

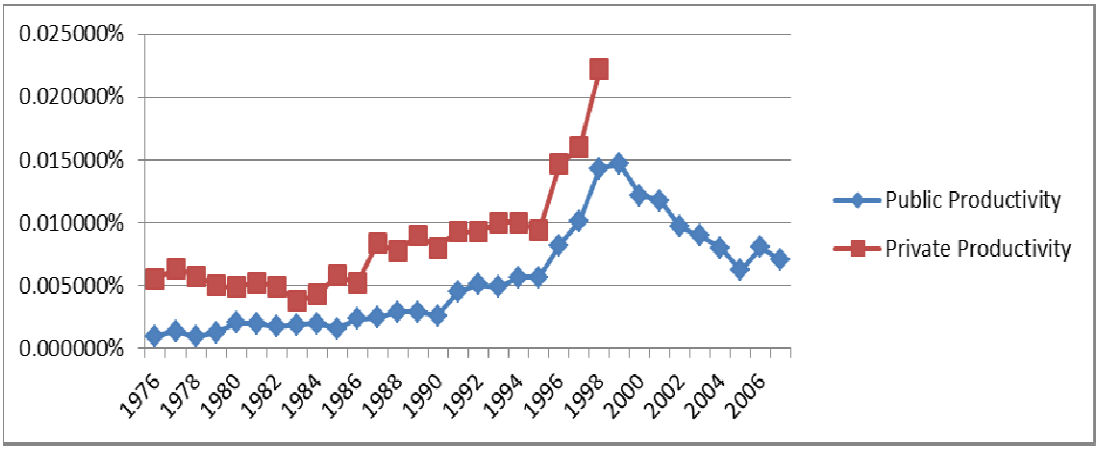

Figure 5.18—Public and Private Agricultural Research Productivity in Nominal Dollars
Source: The USDA Agricultural Research Funding in the Public and Private Sectors[26]

[26] http://www.ers.usda.gov/Data/AgResearchFunding/

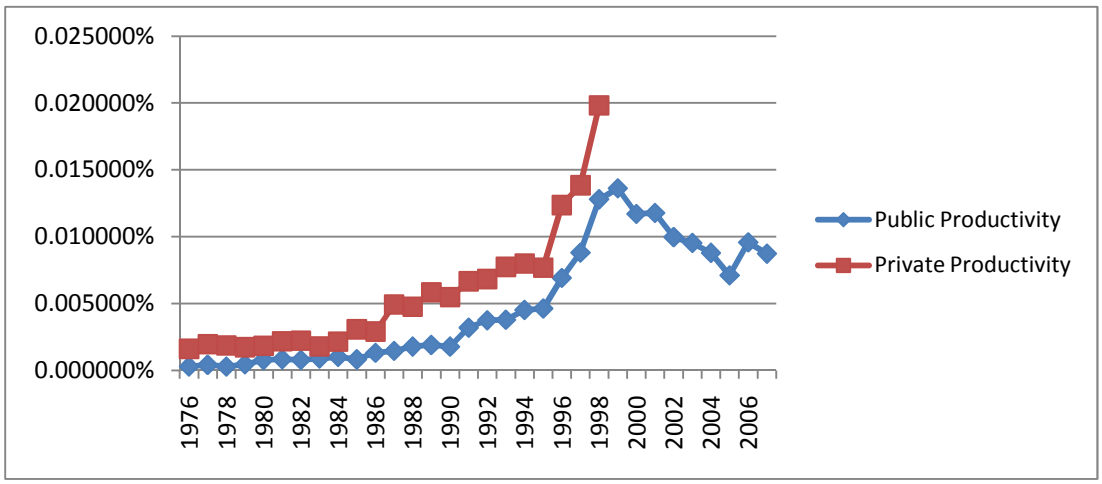

Figure 5.19—Public and Private Agricultural Research Productivity in 2001 Dollars
Source: The USDA Agricultural Research Funding in the Public and Private Sectors[27]

Because the private agricultural R&D data given in the USDA R&D research funding dataset is only up to 1998, we are not able to compare it with the public data from 1999 to 2007. Based on the above two productivity figures, it seems clear that the private sector holds a leading position in both situations. The figure without taking inflation into consideration shows an even higher level of productivity for both the public and private sectors, so we can see that both trends in Figure 5.18 are higher than the two in Figure 5.19.

The two types of funding were close to each other from the beginning to the early 1980s, but after that, the private funding started to grow more rapidly. From 1996 when transgenic crops were first commercialized, the private funding was significantly accelerated. The public funding followed a similar but more conservative growing trend before 1999. From 2000, the public funding gradually decreased.

[27] http://www.ers.usda.gov/Data/AgResearchFunding/

As mentioned at the beginning of this subsection, there is a huge difference in research orientation and motivation between the public sector and the private sector. Therefore, it is understandable that the research productivity of the private sector is higher than that of the public sector, as the private sector's major goal is to pursue profits. We can notice that the two trends do not deviate very far from each other from 1976 to 1994, but the difference became larger from 1995. The reason could be due to the coming commercialization of transgenic crops in 1996. As mentioned above, the categorizing method automatically inflates the ABP quantity of private sector. We can see that the ABP quantity of private sector increased substantially after 1995, which possibly the reason is causing a high value of the ABP productivity of private sector.

5.3.2 The Patent Class Composition of the Public Type and Private Type

The public and private sectors concentrate on different scopes of research, which can also be revealed in the variations in patent class composition in each type. We have counted the ABP quantity and percentage of the top ten class numbers in each type.

Table 5.4—The Comparison of ABP Class Composition under Private Type

1976-2000	TrueABP7600		**2001-2007**	TrueABP0107	
Class	**Quantity**	**% Total**	**Class**	**Quantity**	**% Total**
435	4172	56.86%	**800**	2728	35.74%
800	1525	20.79%	**435**	2322	30.42%
424	616	8.40%	**47**	1028	13.47%
71	515	7.02%	**426**	355	4.65%
426	180	2.45%	**504**	316	4.14%
47	160	2.18%	**536**	281	3.68%
422	28	0.38%	**424**	258	3.38%
436	22	0.30%	**530**	120	1.57%
260	20	0.27%	**514**	99	1.30%
119	10	0.14%	**204**	26	0.34%

Table 5.5—The Comparison of ABP Class Composition under Public Type

1976-2000	**TrueABP7600**		**2001-2007**	**TrueABP0107**	
Class	**Quantity**	**% Total**	**Class**	**Quantity**	**% Total**
435	1663	55.54%	**435**	774	40.59%
800	392	13.09%	**800**	594	31.15%
424	371	12.39%	**424**	146	7.66%
536	121	4.04%	**47**	95	4.98%
530	77	2.57%	**536**	91	4.77%
426	73	2.44%	**530**	55	2.88%
514	71	2.37%	**504**	48	2.52%
71	65	2.17%	**514**	47	2.46%
47	57	1.90%	**426**	25	1.31%
504	30	1.00%	**204**	8	0.42%

In the private type, the top class was 435 in **TrueABP7600** contributing more than half of the total agricultural biotechnology patents. Class 800 placed at the second position by contributing about 20%. In our new identified ABP dataset **TrueABP0107**, class 800 has exceeded class 435 to be the top controlling class number by having a percentage of 35.74%. Even though class 435 has been reduced to the second position, the percentage it contributes to the whole **TrueABP0107** dataset is still 30.42%, which is only 5% lower than class 800. Except for class 424, the remaining less

contributing class numbers become more important in **TrueABP0107** compared with their positions in **TrueABP7600**. Due to the reclassification issues, class 71 has become a rare class in **TrueABP0107.**

In the public type, class 435 maintained its top position within both ranges, but its percentage decreased about 15%. The percentage of class 800 increased from 13.09% to 31.15%. Class 424 remained in the third position even though its percentage dropped about 50%.

Table 5.6—Combination of ABP Class Composition in Both Private and Public Types

1976-2000 Private			**1976-2000 Public**		
Class	**Quantity**	**% Total**	**Class**	**Quantity**	**% Total**
435	4172	56.86%	**435**	1663	55.54%
800	1525	20.79%	**800**	392	13.09%
424	616	8.40%	**424**	371	12.39%
71	515	7.02%	**536**	121	4.04%
426	180	2.45%	**530**	77	2.57%
47	160	2.18%	**426**	73	2.44%
422	28	0.38%	**514**	71	2.37%
436	22	0.30%	**71**	65	2.17%
260	20	0.27%	**47**	57	1.90%
119	10	0.14%	**504**	30	1.00%
2001-2007 Private			**2001-2007 Public**		
Class	**Quantity**	**% Total**	**Class**	**Quantity**	**% Total**
800	2728	35.74%	**435**	774	40.59%
435	2322	30.42%	**800**	594	31.15%
47	1028	13.47%	**424**	146	7.66%
426	355	4.65%	**47**	95	4.98%
504	316	4.14%	**536**	91	4.77%
536	281	3.68%	**530**	55	2.88%
424	258	3.38%	**504**	48	2.52%
530	120	1.57%	**514**	47	2.46%
514	99	1.30%	**426**	25	1.31%
204	26	0.34%	**204**	8	0.42%

As shown in Table 5.6, from 1976 to 2000, the private and public sectors shared six class numbers in common among the top ten class numbers. From 2001 to 2007, the top ten class numbers they owned were exactly the same. In only considering the class composition, it seems that the public and private sectors competed with each other. By only measuring the ABP quantity under each type, it seems obvious that the private sector held the competitive advantage.

However, keeping in mind the limitation in our categorizing method, the ABP quantity under the private type is considerably larger than the quantity under the public type. Due to the limitation of simply counting patent quantity, the results do not present evidence strong enough to conclude the private sector is definitely performing better than the public sector in agricultural biotechnology innovation.

5.3.3 Conclusion

In summary, the comparison of the public and private sectors has been conducted regarding various aspects of the agricultural biotechnology industry. Apart from previous comparisons about public and private agricultural research expenses and their relationship with agricultural GDP, we have also focused on ABP research productivity figures. Data and analysis presented seem to indicate that the private sector is holding the leading position and growing more rapidly. The reason could be due to the higher research flexibility of private companies, as they possibly concentrate on developing derivatives from the basic research done by the public sector with the goal to optimize profit.

According to the statistical results about the patent class composition in each sector, we have found that both the public and private sectors share the exact same class composition structure in the **TrueABP0107** dataset and have six class numbers in common in the **TrueABP7600** dataset.

It is possible that they are competitive in agricultural biotechnology innovations in the fields filed in the definitions of those classes. However, it is still difficult at this point to draw any conclusion about the competitive advantage of either sector. Even though the private sector holds a much larger number of ABP quantity than the public sector, there is no evidence to show that the private sector definitely performs better than the public sector, because each patent has its distinct value and importance,.

5.4 ABP vs. Overall Utility Patents

Besides the absolute developing trend of agricultural biotechnology patents, it is also important to know how ABP develops compared to the overall utility patents. Some common macroeconomics variables can influence the agricultural biotechnology patents and the overall patents simultaneously, such as GDP, the unemployment rate representing the economic environment, or the inflation index. The relative figure of ABP to overall patents could help reduce the impact of those macroeconomics variables, and illustrate a more objective ABP developing trend.

5.4.1 Patent Grants

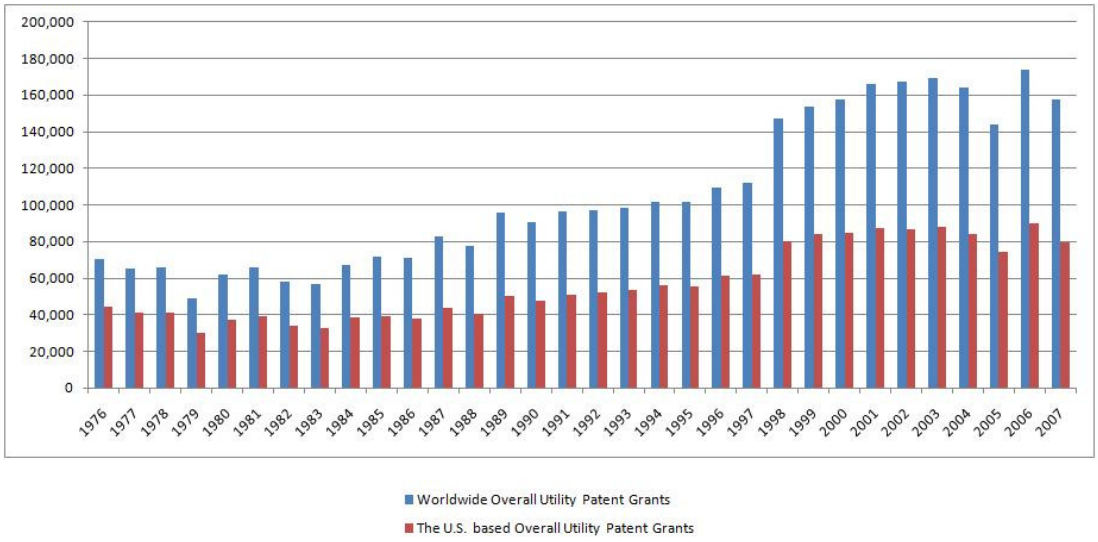

Figure 5.20—The Developing Trend of the Overall Utility Patents 1976-2007

Figure 5.20 depicts a general increasing trend of the overall patents granted from 1976 to 2007. A significant increase appeared in 1998, which is consistent with the one in the absolute ABP developing trend. Compared with the absolute ABP distribution, the overall patent distribution displays a smoother shape. The ABP trend reached its peak value in 2001 but the overall patent trend hit its highest point in 2006. Nevertheless, the year 2005 was the lowest production year in both cases in the small range from 2001 to 2007.

Some common macroeconomic factors can influence both the ABP quantity and the overall patent quantity at the same time. For example, in a bad economic environment, normally research and development funds are reduced, so it is possible that people are less motivated and less capable to produce a great deal of innovations. By considering this relative figure of ABP to the overall utility patents, we would be able to diminish

the effects from those macro level factors and only focus on more specific factors dominating the development of ABP.

We define a percentage which is the proportion of the total granted patents filed under the agricultural biotechnology categories. As shown in Figure 5.21, the value of the percentage is relatively small and the maximum value is only about 1% in 2001. This can indicate that the agricultural biotechnology patents are only a small subset of the overall utility patents.

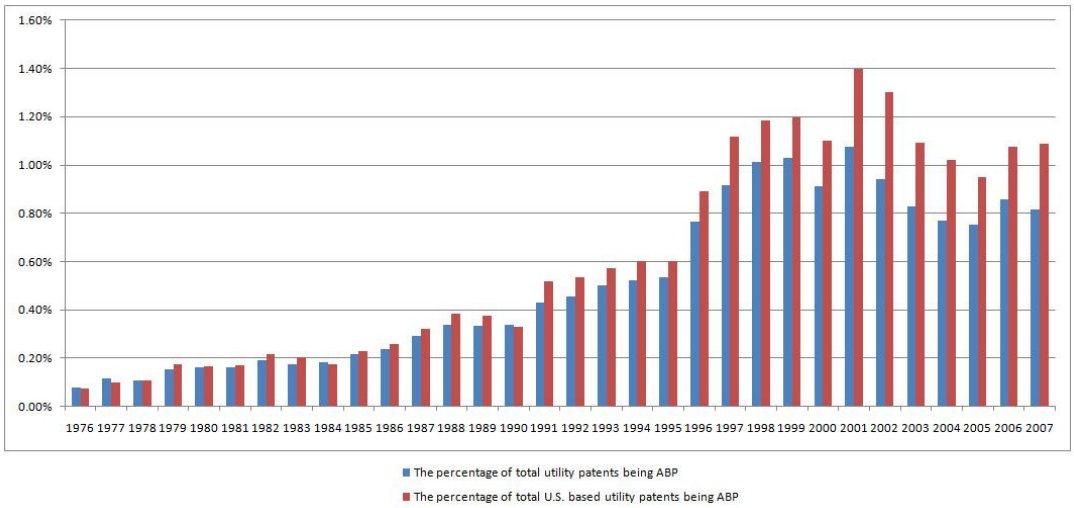

Figure 5.21—The Developing Trend of the Percentages of the Overall Utility Patent Grants being ABP

As we can see, the percentage trend looks moderately similar with that of the absolute ABP quantity. The increasing trend lasted from 1976 to 1999 with a significant jump in 1996. The peak value appeared in 2001 and followed by a downturn until 2006. In both cases, the minimum point can be observed in 2005. At this point, we can

possibly conclude that the developing trend of the ABP is highly determined by pure agricultural biotechnology industry factors rather than macroeconomic changes.

5.4.2 Patent Applications

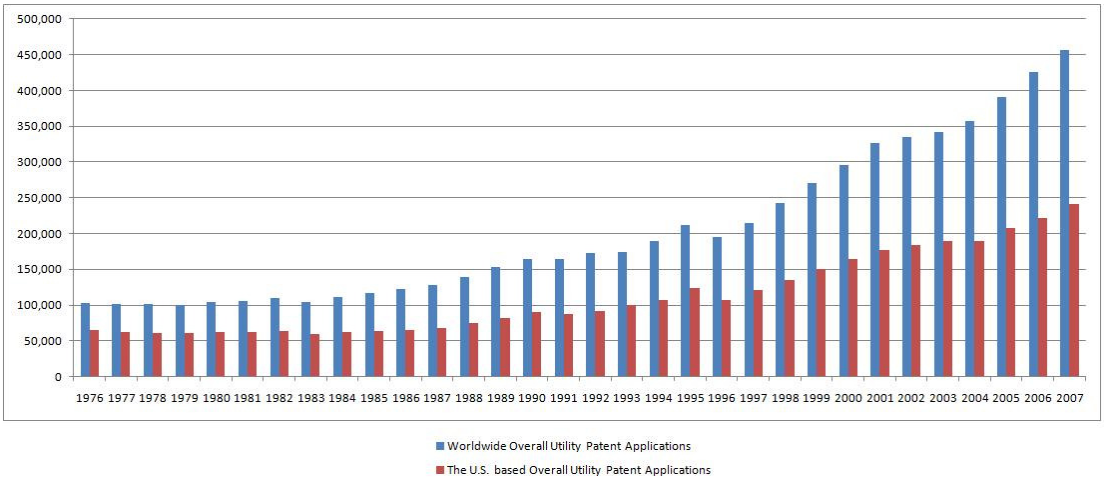

Figure 5.22—The ABP Percentages of the U.S. based and Worldwide Patents

In comparison to the developing trend of patent grants, the patent application distribution as shown in Figure 5.22 looks to be more smoothly increasing. It is understandable that applicants are more inclined to dedicate themselves to innovation, due to the technology development and the maturity of innovation regulation.

Due to this truncation problem and the empirical result of the identified 2001-2007 ABP dataset, in accounting the ABP application, we have decided to only consider the patents issued before 2001. The seven years can serve as a buffer to allow more applications and at the same time reduce the truncation effect.

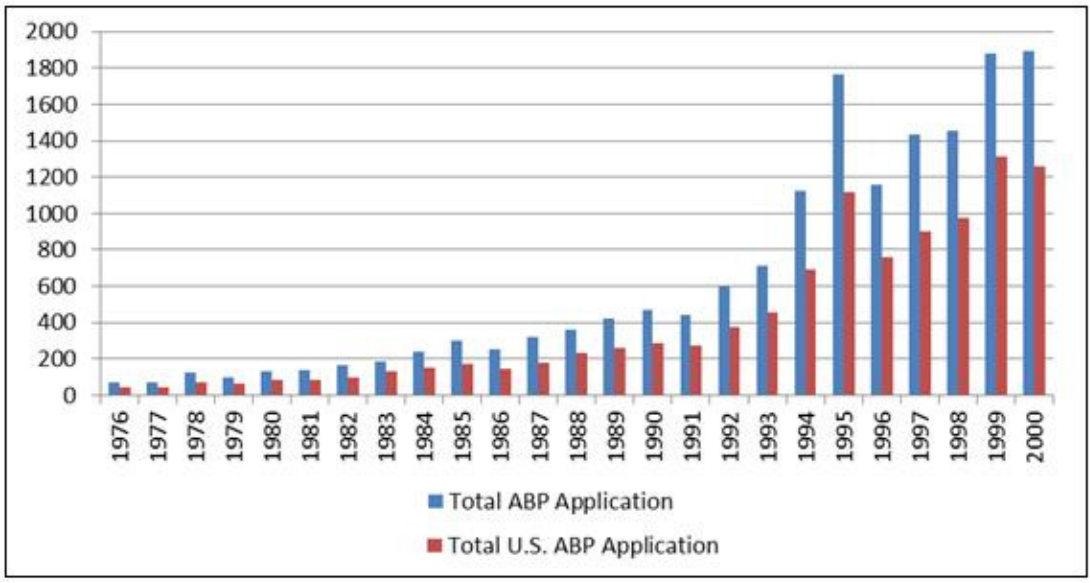

Figure 5.23—The Developing Trend of the U.S. based and the Worldwide ABP Applications

The application trend has shown steady growth except for a few sudden jumps in 1995, 1999, and 2000. Differently from the grants trend, the application trend can be treated as a way to preview certain changes in the agricultural biotechnology industry, for example, the extremely large number of ABP applied in 1995 compared with the ABP quantity in the previous and subsequent years. Meanwhile, a large number of applications may cause pressure on the approval process. Three years can only be treated as an empirical average result to roughly tell the time difference between ABP application and approval because patent processing speed varies in different times. In any case, a peak supply in patent application will possibly result a certain amount of pressure on subsequent patent approvals. Therefore, the extremely large number of ABP in year 1995 may influence on the number of ABP grants from 1996 to 1998. And the peak applications in both 1999 and 2000 may be the reason for the highest grants number in 2001.

Furthermore, we have also calculated the percentage of patent applications filed in agricultural biotechnology categories. The percentage distribution shape is generally similar to that of the absolute ABP applications. The percentage reaches its highest value in 1995 as shown in Figure 5.24.

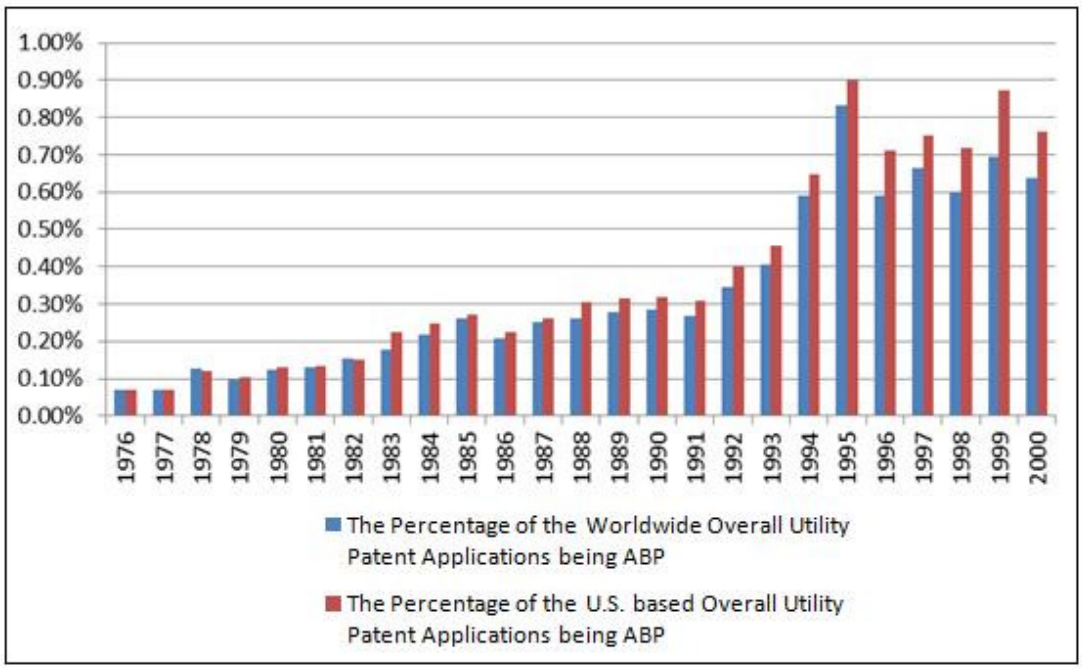

Figure 5.24—The Developing Trend of the Percentages of the Overall Utility Patent Applications being ABP

5.4.3 Conclusion

The purpose for investigating the relative figure of ABP to the overall utility patents is to observe whether it is different from the developing trend of the absolute ABP quantity. The results suggest that the macroeconomics variables do not have strong power to determine agricultural biotechnology innovation. Referring to the

application data as well, it is possible that peak patent application years would give high pressure on the granting of patents in the subsequent years.

5.5 International ABP

We define ABP issued to assignees that are not U.S. based entities as international ABP. The data of international ABP are more conservative in our dataset as at this point we only count the international patents applied through the USPTO. There are components of ABP applied for and published in their own countries, but in this thesis, we only focus on the international patents being applied through the USPTO.

Some people may be curious to know why foreign countries are also interested in applying for agricultural biotechnology patents in the United States. There could be various explanations. The first reason could be due to market domination, as consumers' attitudes to the products involved in agricultural biotechnology may vary across in different countries. For example, European consumers' attitudes toward the use of genetic modification in food production are very negative (Grunert *et.al,* 2003). It is beneficial for those European based ag-bio firms to expand their market on a global stage, especially considering the large market in the United States where consumers are more willing to accept genetically modified food.

Intellectual Property laws in different countries cover different patent regulations and guarantee different protections for the rights of patent owners. For the purpose of expanding their business scope to the United States, it is beneficial to be covered by the patent protection system in the United States. Thus, applying for patents through the USPTO can further strengthen the successful business expansion to the United States.

5.5.1 International ABP vs. the U.S. based ABP

Admittedly, the U.S. based ABP quantity should hold a leading position among the worldwide ABP data, because domestic applicants are more willing to apply for patents in their own countries. The inventors living in the United States are more familiar with the patent application procedure, and meanwhile the intellectual property rights guaranteed through the patentability can be more directly applied in their local country. Based on the patent data from 1976 to 2000 and the new ABP data identified by us from 2001 to 2007, the dominating percentage of the U.S. based assignees is around 60% to 70% (shown in Figure 5.25).

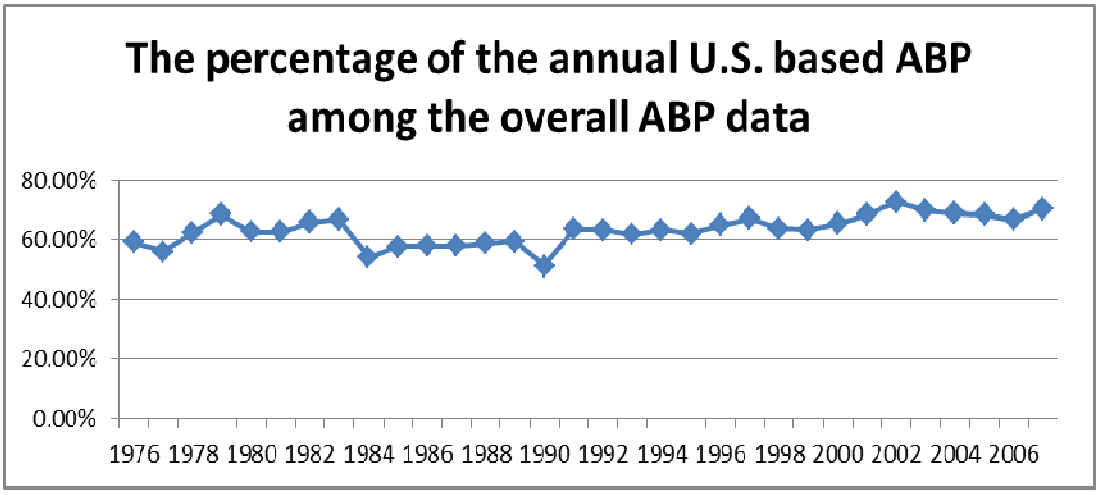

Figure 5.25—The Percentage of the Annual U.S. based ABP among the Overall ABP Data

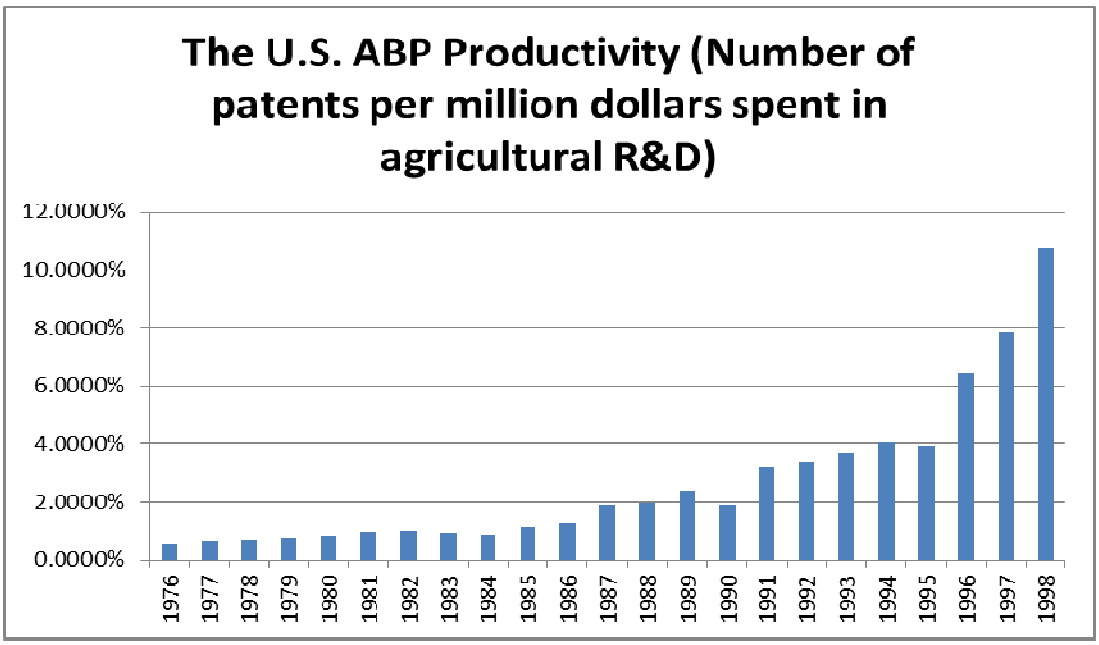

Figure 5.26—The U.S. ABP Productivity (Number of patents per million dollars spent in agricultural R&D)

We calculated the U.S. ABP Productivity as the number of ABP per million dollars spent in the agricultural Research and Development in the United States. The total agricultural R&D funding data is obtained from the same dataset "Agricultural Research Funding in the Public and Private Sectors" mentioned in the section 5.3, which is the sum of the R&D expenses from both the public and the private sectors.

The same assumption treating the scope of the term “agriculture” as previously used in the definition of agricultural biotechnology still holds. Based on the results in Figure 5.26, the U.S. ABP Productivity has improved substantially in the long run, especially from 1995 to 1998.

However, even though the ABP percentage held by the United States has been impressive for many years, it does not prove that the United States is definitely holding a leader role in agricultural biotechnology innovation. As has been explained previously, the patent data we developed are based on the data obtained through the USPTO. A simple issue could be raised that the applicants in foreign countries may have some restrictions in applying for patents through the USPTO, and it is rational that not all the foreign applicants will necessarily file their inventions in the United States. Yet, the data of the foreign innovations filed in the United States could be treated as an index to view the development of agricultural biotechnology innovation, which indirectly reflects the technological progress and policy adjustments in those foreign countries.

5.5.2 Case Analysis for Germany, Japan, Australia, and China

Germany and Japan are often being considered as a pair of analogues countries because they share some multiple parallel historical paths, such as their industrialization in the early 1900s, authoritarian nationalism in the 1930s, later

invasions of neighboring countries in Europe and Asia, and their economy booms after WWII. Lehrer and Asakawa (2004) concluded that another recent similarity between these two countries was policy change stimulating their biotechnology innovation.

Australia is a major agricultural producer and exporter. Brennan and Bantilan (2003) assessed the spill-over effect of Australia generated from the cost reduction in research into sorghum and chickpeas in developing countries. Moreover, China with its 4th largest GDP and agriculture portion GDP of 10.6% in 2009 also grabs attention from various economists, especially in light of its economic boom in recent years.

In this section, we select four countries Germany, Japan, Australia, and China as representative examples to analyze the quality and quantity of ABP in each country. We define a patent's country to be its assignee's country, not its inventor's country. For example, the country of a patent invented by a Chinese employee working in an ag-bio firm registered in the United States is still considered to be the United States. Because of the German Reunification in 1990, we select patents belonging to both the Federal Republic of Germany (DE) and the German Democratic Republic (DDR) from 1976 to 1990.

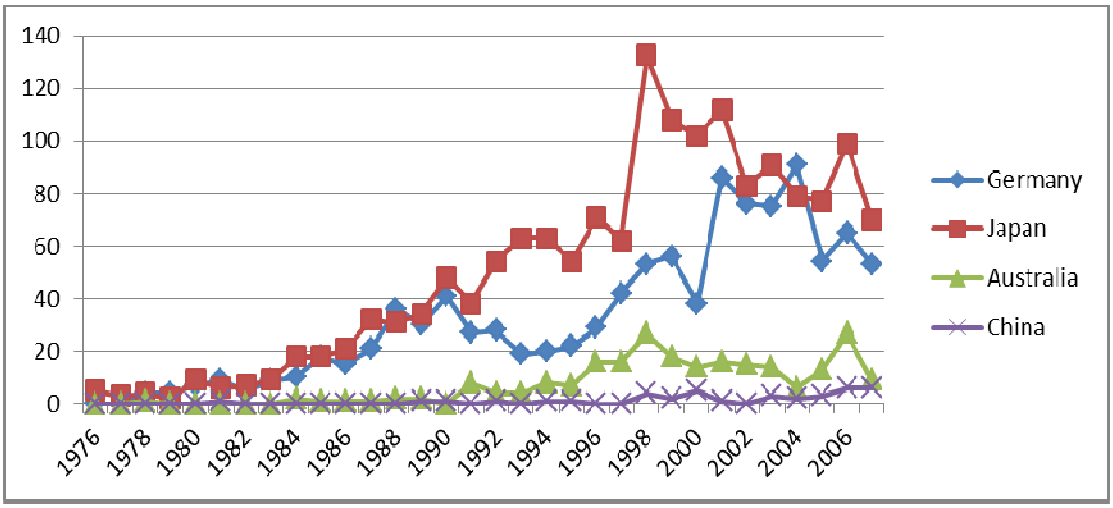

Figure 5.27—ABP Quantities of Germany, Japan, Australia, and China 1976-2007

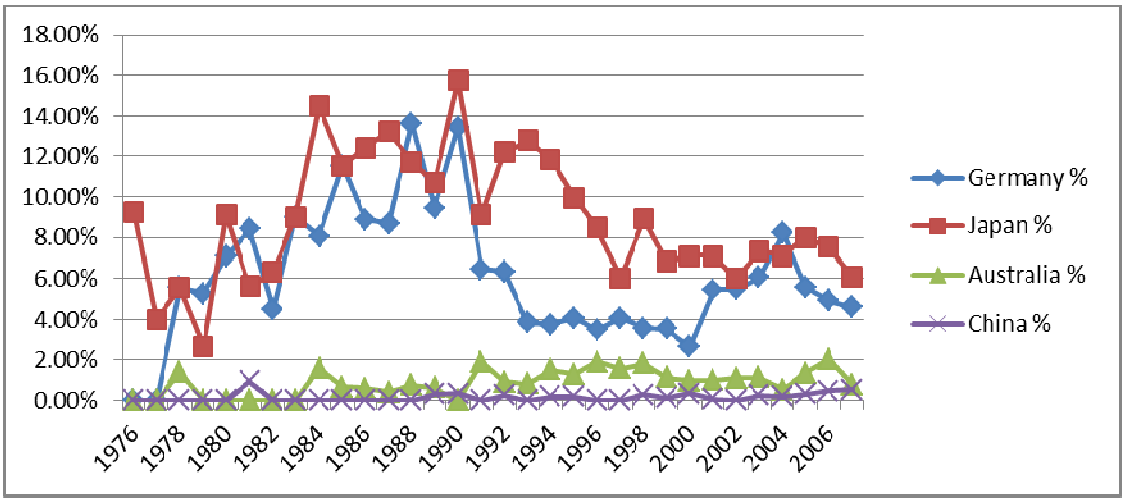

Figure 5.28—ABP Percentages of Germany, Japan, Australia, and China 1976-2007

As shown in Figure 5.27 and 5.28, Japan was holding a leader position among these four countries. Before 1990, the percentages of ABP held by Japan and the combination of Eastern and Western Germany were relatively similar, but Japan was slightly more productive. However, after the German reunification in 1990, the ABP quantity of the newly reunited Germany started to decline, and the percentages dropped significantly as compared to Japan's increasing ABP quantity from that time. In the M&A section, we have discussed that the drop of ABP quantity is possibly due to M&A activities. Similarly, a merger case of two countries can be more difficult and

complicated, so it is understandable that the reunited Germany performed less satisfactorily as compared to the combination of the two separate countries.

Japan reached the highest ABP quantity in 1998 and Germany was also in a climbing trend at that time, which was perhaps due to the initialization of transgenic crop commercialization. After the peak value, Japan seemed to follow a general downward trend, but Germany caught up rapidly from 2000. The ABP quantity and percentages owned by Australia and China are relatively smaller. The peak values of Australia were in 1998 and 2006, which is consistent with the overall ABP trend.

Besides the long term tendencies of each country, we are also interested in knowing the detailed classifications filed in each country's ABP dataset. For this purpose, we are able to know the research concentration in each country. As shown in the following four figures of their ABP quantities from 1976 to 2007, class 435 and 800 are the top two classes for each country. These two classes are also the major core classes in representing agricultural biotechnology definition. Referring to the following patent class definitions again, we could see a common research interest in chemistry related Molecular Biology and Microbiology and Multicellular Living Organisms, for all the four countries. Class 435 holds its absolute leading position in the ABP database of both Germany and Japan.

Besides the two important class numbers, Germany also has its ABP innovation

focusing on “Plant Protecting and Regulating Compositions” (class 504) and “Chemistry: Fertilizers” (class 71). Class 47 with a definition of “Plant Husbandry” is at the third position for Japan and China. Australia has class 424 with a definition of “Drug, Bio-Affecting and Body Treating Compositions” at its third position.

Class 435 Chemistry: Molecular Biology and Microbiology

Class 800 Multicellular Living Organisms and Unmodified Parts Thereof and Related Processes

Class 47 Plant Husbandry

Class 504 Plant Protecting and Regulating Compositions

Class 424 Drug, Bio-Affecting and Body Treating Compositions

Class 71 Chemistry: Fertilizers

Source: The USPTO Website: US Classes by Number with Title Menu[28]

[28] http://www.uspto.gov/web/patents/classification/selectnumwithtitle.htm

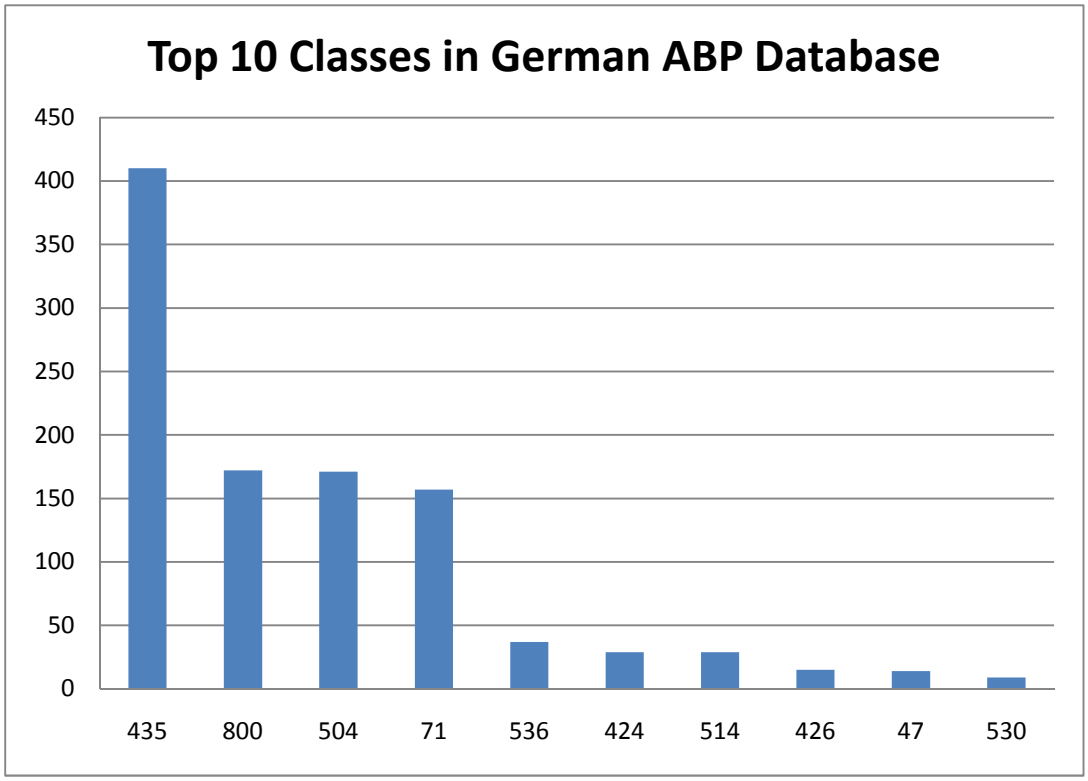

Figure 5.29—The Detailed Classifications of Germany 1976-2007

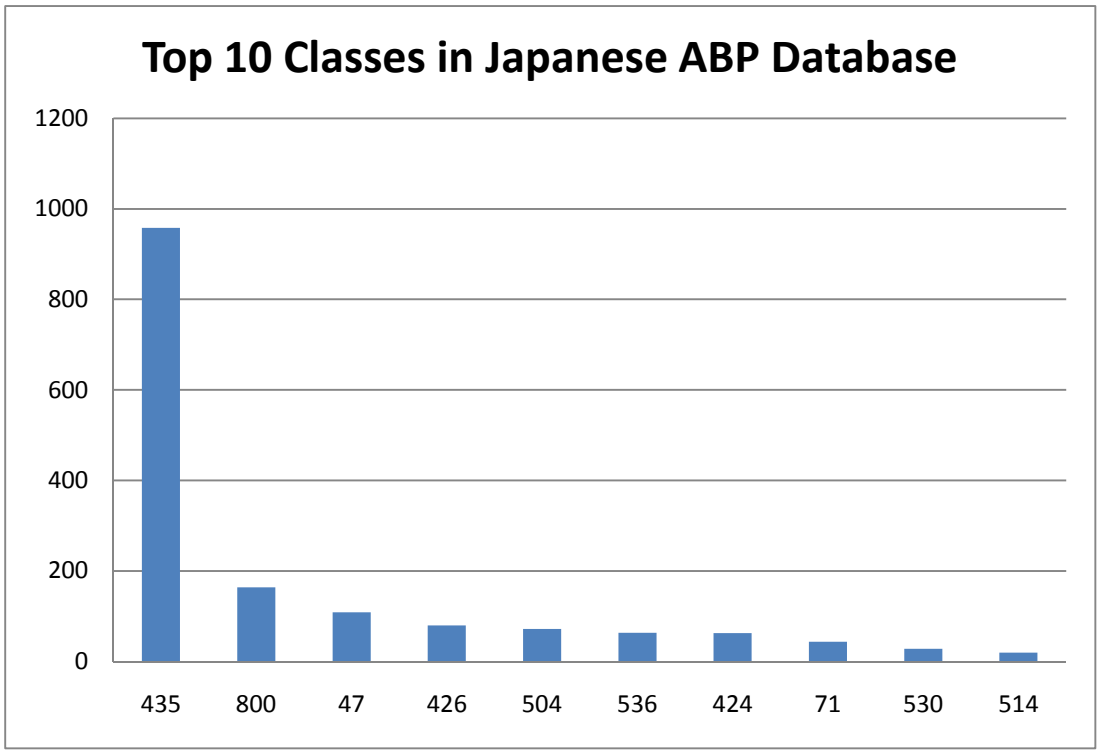

Figure 5.30—The Detailed Classifications of Japan 1976-2007

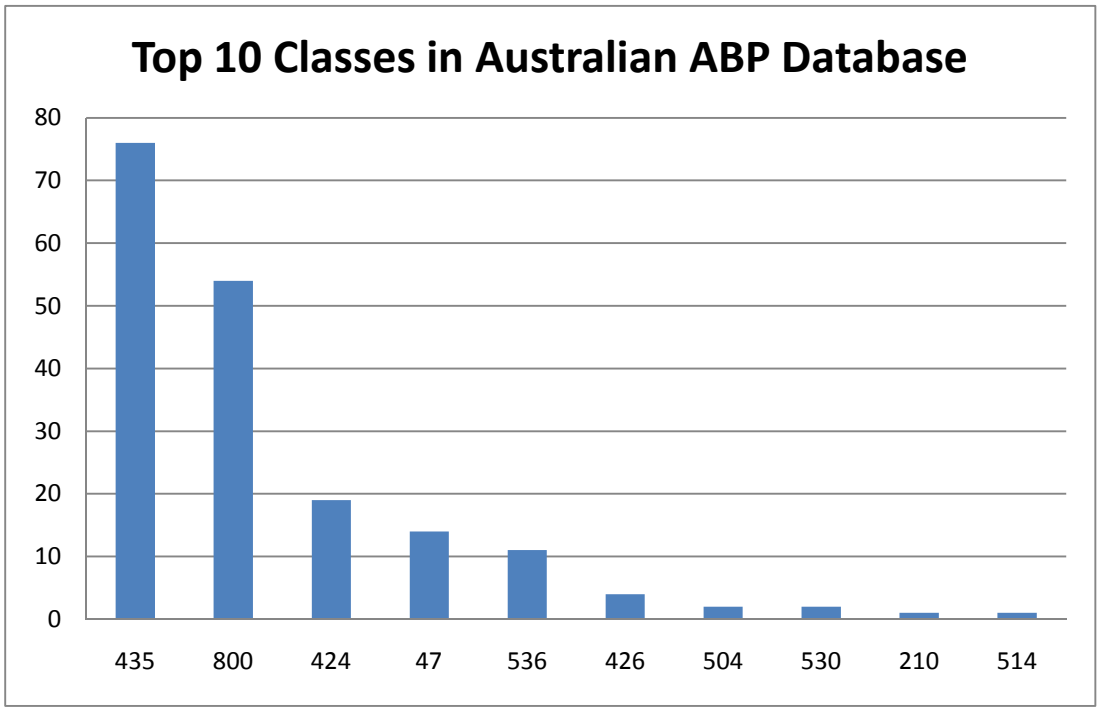

Figure 5.31—The Detailed Classifications of Australia 1976-2007

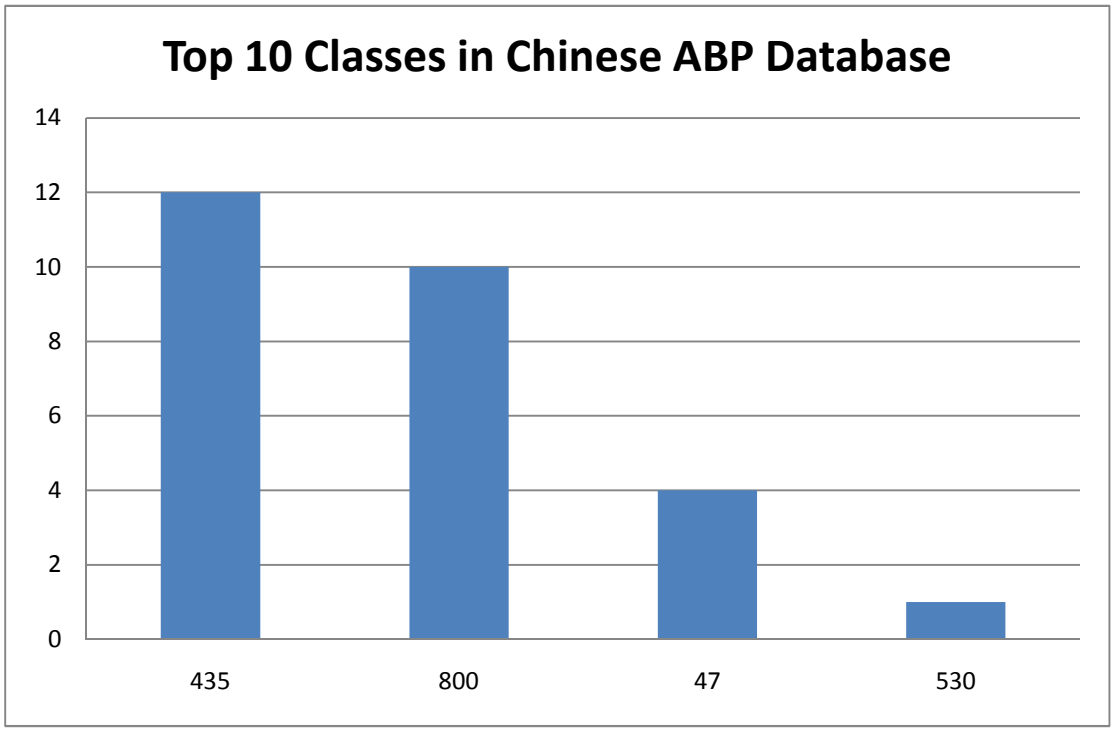

Figure 5.32—The Detailed Classifications of China 1976-2007

5.5.3 Conclusion

Although the percentage of the U.S. based ABP among the worldwide overall ABP issued through the USPTO is about 60% to 70%, without further information about the ABP innovation in the foreign countries apart from the United States, it seems clear that the United States was holding a leader role in agricultural biotechnology innovation. The ABP productivity of the United States also followed a general increasing trend. Germany and Japan are two important foreign countries who have contributed considerably to the USPTO ABP database. Germany followed a downward trend around the time of its reunification in 1990 but caught up rapidly especially after 2000. Japan kept continuing the increasing trend until it reached its peak value in 1998, and started to decline its contribution after that. The classification detail under each country once more proves that 800 and 435 are two major classes indicating an agricultural biotechnology orientation.

5.6 Conclusion

The main purpose of this whole Economics Analysis section is to examine the characteristics of the ABP data, both the data provided by the USDA and the new data identified by us, and meanwhile to explore some possible reasons behind the ABP developing trend.

According to numerous previous studies, a large amount of merger and acquisition in

agricultural biotechnology can lead to an increased industry concentration, and consequently can lessen the motivation for ABP innovation. We did case analyses for the top two firms in the agricultural biotechnology industry – DuPont and Monsanto. In these two case analyses, the trends of their annual ABP quantity follow a consistent shape corresponding to their similar M&A activities. We cannot conclude that the downturns after their M&A activities are definitely due to their mismanagement because of the lack of further supporting evidence. However, the analysis of their profitability performance does confirm that they both experienced some financial shortages after their M&A activities.

Besides analyzing the possible factors driving the ABP annual quantity, we have also taken a look at the ABP characteristics in comparing the ABP quantity in the public sector verses the private sector.

By having different research interests and goals, the private sector aiming chiefly to profit optimization has a much higher ABP quantity compared to the public sector. It seems clear that the two sectors maintain competitive roles as the major patent class composition is same in both. However, without knowing the value of each agricultural biotechnology patent, it is meaningless to draw the conclusion that the private sector is holding a competitive advantage. The private sector was also holding a higher value in ABP productivity which is calculated as the number of ABP per million dollars spent in agriculture R&D expenses.

Based on the analysis of the comparison between agricultural biotechnology patents and the overall utility patents, it is likely that the ABP quantity was not driven by macroeconomics factors. The results show that the developing trend of the percentage of the overall utility patents that are ABP is reasonably similar to the absolute ABP trend.

Given that foreign countries participate actively in filing agricultural biotechnology patents through the USPTO, it is important to explore the motivations of these international countries and the specifications of their ABP. Therefore, we chose four representative countries Japan, Germany, Australia, and China as examples. Japan and Germany were the two leading countries according to their ABP quantity. Germany was to some extent less productive than Japan especially during the time after its reunion in 1990. Australia and China contributed less importantly to the total ABP grants, but each country's annual ABP quantity followed a general increasing trend.

Last but not the least, except for section 5.4, we checked the patent class composition in the rest of the subsections with different perspectives. We compare the class composition change before and after M&A activities, between the ABP assignees under the public and private sectors, and across different international countries. All the results consistently confirm that classes 800 and 435 are the most representative class numbers composing the largest proportion of the total ABP database. In addition, the contribution of class 800 increased in the new ABP dataset identified by us.

CHAPTER 6

LIMITATIONS, RECOMMENDATIONS AND CONCLUSIONS

6.1 Limitations and Recommendations

We have been focusing on identifying agricultural biotechnology patents by using a machine learning methodology in this thesis. In the identification procedure, we have adopted several assumptions to simplify some problems. In addition, in the Economics Analysis section, due to some unknown background information and unobtainable data source, there are further constraints on several parts of our data analysis. In the last section, we summarize all the limitations and recommendations in this thesis, and give recommendations for the possible future work that can be done by other research fellows.

The purpose of the training set is to provide an aggregated data collection containing both true data and false data, which means the true ABP identified by the USDA plus patents filed under other general topics. The size of the true ABP data issued between 1976 and 2000 is only 11,073 patents. However, considering the false ABP dataset which are the remaining patents filed under the same class numbers, the size is extremely large. In order to reduce the complexity of the data processing, we have to control the size of the false ABP data. We found that the true patents filed under these six class numbers contribute as 84.37% in the total 11,073 dataset, so we can see that

these six class numbers are very representative. This is also confirmed by the high recommendation of the USDA. For this reason, we only include the false ABP filed under the six major class numbers. However, this effort also brings in a limitation due to the removal of the patents filed under the less important class numbers. Besides the six class numbers, the true ABP data also incorporates some other less important class numbers. At this point, the false ABP data including only the six class numbers is not balanced with the true ABP data.

Therefore, the prediction accuracy in using this training set can be reduced to a certain extent. We recommend that other similar research work incorporate more class numbers to give a broader inclusion of initial patent candidate collection.

Additionally, in the section using the Bag-of-Word model to transfer the patent textual information to a vector, we only choose the top 1000 keywords appearing in the titles and abstracts of the total patent data. This also reduces the data processing complexity. Ideally, it is better to choose as many keywords as possible to approximate a better agricultural biotechnology definition. Therefore, only considering the top 1000 keywords can be treated as another limitation.

Besides the modeling limitations, the selection methods also involve some restricted assumptions. Under each major class, we assume that the percentage of patents being ABP in the range of 2001-2007 is equal to the ones in the range of 1976-2000.

However, in reality, the percentage may have a wide range of variety because the agricultural biotechnology industry is developing and there may be numerous policy changes over time. Nevertheless, it may be difficult to estimate the changes in the percentage for future years. Therefore, we recommend that some high level statistical methods be applied to give a more accurate prediction based on the percentage data in historical years. Moreover, since the patent prediction score was generated by our machine learning methodology, the value of the score consequentially may have some unavoidable restrictions. Therefore, choosing patent candidates according to the value of their scores can be treated as another limitation.

Thus, we would like to recommend that future similar research work identifying agricultural biotechnology patents consider some possible methods in other fields. For example, they could try to build models by using econometrics and statistical knowledge to do the prediction based on the characteristics of historical ABP data.

In the economics analysis section, some background information is unknown and some data is not available to use, so we have to make assumptions to smooth the elaborations. In the analysis about the patent applications about the ABP and the overall utility patents, we have indicated a truncation problem due to the approval time after a patent has been applied for. Since patent applicants need to wait for a certain amount of time to get their patent approvals, patents applied for in more recent years will be treated unfairly in our data collection method. For example, in our patent

database with patent data up to 2007, a patent applied for in 2005 may be approved in 2008, but this patent will not be shown in our database as we collected patents with approval dates no later than 2007. There is probably no effective way to solve this truncation problem but we can narrow down our research focus by not considering the relatively more recent patents.

In the section of Private Sector vs. Public Sector, we calculated the U.S. ABP productivity rate by using the agricultural R&D funding data published by the USDA to give an explanation about the ABP productivity at the macro-level. Since the USDA did not give a clear definition of the scope of the word "agricultural", we assume that R&D funding can be approximated as the R&D funding spent in agricultural biotechnological fields.

6.2 Conclusion

Agriculture can be treated as a fundamental industry playing an essential role in providing sources to other industries. Agricultural biotechnology is an important component helping lead to biotechnology developments in the agriculture industry. As a result, agricultural biotechnology patents can be viewed as an index to show the developing directions in agricultural biotechnological industry, and meanwhile serve as a supportive factor to guarantee a protection of agricultural biotechnological innovations.

To date, the ABP data has been updated up to 2000 by the USDA, and after that neither the USDA nor other research institutions have done any new ABP identification work for patents issued after 2000. This missing data already create a decade long truncation problem. The major goal of this thesis is to solve this problem by identifying more recent agricultural biotechnology patents. Apart from checking each patent manually, we adopt a machine learning methodology to generate a prediction score for each patent according to its extent of matching to the selected agricultural biotechnology keywords.

Given the prediction scores representing the degree of possibility of agricultural biotechnology qualification, we are able to select patents according to their prediction scores. After several tentative selections based on different criteria, with the consideration of the reclassifications, the final plan is to incorporate the full class of 47 but treat other large classes equally. We assume that the percentage of patents being ABP in the period of 2001 to 2007 under each large class number is the same as the one in the period of 1976 to 2000. Thus, the same percentage of patents can be selected by ranking their prediction scores. For patents under the small class numbers, we only select those with positive scores.

By using the final plan, we have identified 9,539 ABP issued to worldwide entities and 6,566 ABP solely to U.S. based entities. The ABP quantity reached its highest value in 2001, followed by a decreasing trend until a jump in 2006.

We have conducted economics analysis based on the above results. Given vigorous merger and acquisition activities done by DuPont and Monsanto, we divide the ABP database into two parts according to a selected year with most active acquisitions. Therefore, we are able to compare several ABP characteristics before and after the most active acquisitions done by each firm. The comparison results reveal that both firms experienced declines in their ABP quantity within a certain amount of time after their active acquisitions. Similarly they both experienced financial shortage after their major acquisitions. In addition, we find that the participation of class 800 increased and the participation of class 435 decreased after the major acquisitions of each firm.

According to the organizational type of assignees, we divide the whole ABP database into two categories: public and private. Based on our statistics about the ABP quantity under each type, it seems clear that the private sector is holding a leading position in both the absolute ABP quantity and ABP productivity. However, there is no strong evidence to conclude that the private sector definitely grabs competitive advantage because the importance of each patent can vary widely.

As shown by the comparison results of the ABP to the overall utility patents, it appears probable that the developing trends of agricultural biotechnology patents are not determined by macroeconomics factors but by those factors specified in that industry itself.

Although the percentage of ABP held by the U.S. based assignees over the total ABP is around 60%-70%, without knowing the ABP application details in foreign countries, we are not able to confirm that the United States is absolutely leading in the worldwide agricultural biotechnology innovation. Germany and Japan are two major contributors in the pool of international ABP.

In order to smooth and coordinate the whole research procedure, we have had to make certain unavoidable assumptions to simplify some problems, which has resulted in limitations to this research. We recommend that future similar research make reference to our work and conduct further investigation on certain issues we raised in section 6.1.

APPENDIX A

THE LIST OF THE PATENT NUMBER OF THE ABP IN THE DATASET

TRUEABP0107

FOLLOWED BY THE ORDER OF PATENT ISSUING TIME

(COLUMN LEFT TO RIGHT)

7207140	6514502	6528311	6911338	6762153	6756530	7138571
6631585	6303117	6716631	7186508	6432879	6759578	7176361
6357171	6500419	7148054	6649343	6737382	6759580	7183470
6308458	6713077	6569678	6391603	RE038188	6765132	7235721
6282837	6635245	6451552	7192753	7037880	6770802	7259300
7069689	6207165	6521408	6472213	6268310	6774289	7273970
6868634	6261561	6204061	6355426	6383987	6774290	7164059
6219964	6833135	7129050	6344347	6887828	6777599	7205451
6481154	6344193	6255115	6706517	6461997	6781042	6194638
6684564	6231868	7273749	6737253	6337305	6781043	6184449
6493990	6319497	6482647	6265159	6770600	6784349	7071376
6286253	6689357	6221661	6197499	6743755	6784350	7193136
6321484	6540998	6316184	6503716	6335308	6806408	6919493
6173525	6942860	6319716	6649349	6455472	6809240	7129396
7168207	6942849	7217514	7056732	6417152	6815592	7179964
6212824	6495146	7235386	7005297	6703357	6846976	6849779
6668485	6627205	6174668	6214590	6602842	6849791	7282625
6606822	6517842	6825006	6743627	6448226	6855878	6677505
6401386	7223409	7208318	6913880	6573240	6864411	6323392
6651382	7235235	6379895	6436641	6593293	6872873	7135619
6173527	6846482	6416952	7276335	6197747	6878863	7166772
6490824	6440469	6232106	7056659	6855683	6881880	6320106
6601340	6224878	6514735	7256031	6900173	6897361	6215041
6374538	6200561	6589775	6858429	6277814	6897363	7105723
6167652	6746671	6316195	6406896	6710027	6903254	6310272
7131234	6623750	6977161	7037703	6331531	6933425	6844486

6766615	6372211	6500617	6696271	6262018	7122725	6337430
6751902	6919084	6589735	6893837	6541448	7154030	6501007
6705043	6306386	7238508	6475736	6242420	7161071	6362393
7174672	6780408	6204045	6762018	6689743	7161072	6472588
7237358	6960342	6413762	6300074	6583107	7161073	6822145
6397520	6346245	6514754	7238481	6326351	7164066	6956151
6192624	6517843	6514760	6270958	6624139	7164067	6403864
7269923	6379663	6291170	7160682	7129212	7166781	7214856
6393763	6299882	7049102	7205104	6468984	7166782	7176351
6389751	6183750	7115420	6653108	6211216	7169984	6268547
6907691	7094417	6929928	6432637	7053063	7173173	6977328
6343435	6337068	6841370	6251588	6852705	7173174	7189895
6804912	6616950	6642036	6265201	6333302	7176362	6630620
6449898	7179457	6991922	6825001	7078388	7176363	6632985
6434881	6977078	6300075	6500650	6528484	7179971	6803502
6243987	6605281	6951744	6825009	6528480	7183472	6803503
6729068	7132108	6306591	6225093	6521590	7186902	6803504
6286250	6770273	6846622	6335159	6194389	7186905	6831209
6594950	6605283	6632653	6638735	6803361	7189901	6909033
7024817	6800289	6242191	6602682	6451770	7189902	7026531
6487817	6605285	7074565	7186525	6624145	7193145	7078594
6978575	7037501	6300069	7141388	6500801	7196254	7078599
6807769	6759048	6358712	6235514	7091177	7199289	7132592
6883271	6558674	6521435	6251593	6831062	7202402	7164064
6688037	6248321	6214598	6291218	6638910	7214864	7186894
6823623	7169398	6929950	7258976	6916782	7230172	7189896
6378245	6287585	6541233	6958236	6417163	7241942	7196249
6308456	6217882	6268147	6946250	6291426	7241943	6307124
6735902	6585978	7067285	RE037187	7056888	7259301	7244879
6508033	6395283	7241619	6777181	6875766	7259302	7071378
6629384	6537577	6203988	6297013	6632792	7262345	6169230
6578318	6890530	6387702	6391546	6441003	7262346	6169231
6223466	6872388	6395523	6245518	7026286	7265279	6252146
6789353	6767566	6524811	6331394	7176190	7268277	7135614
6901699	6210665	6506592	7094535	6809078	7268278	7244877
6360479	6858205	7037681	6245536	6376473	7273971	7045680
6820367	6410032	6524830	6251636	6818628	7273972	6245968
6185865	6916477	7214525	6261804	6319901	7276650	6297427
6637156	6998126	6174709	6800449	6174860	7282629	6175063
6360485	6656477	6338965	6841364	6277823	7285706	6188002
6594949	6641819	6586249	7083909	6656908	7285707	6372969

6877275	6682737	6869797	7279335	RE039240	7288700	6855877
6182395	6730307	6322988	6514705	6200951	6921849	6864409
6298601	6977079	6355421	6942973	6399571	7202401	6268549
6341446	7241450	6528267	6309868	6605594	6933427	6927321
6477804	7264802	6949343	6472184	6750222	6987217	6995300
6523305	6569422	6395528	6376216	6613752	7026533	6344598
6655086	7070789	7029896	6485944	6486157	7030303	6372967
6662495	7090852	6780591	6511803	6548508	7064255	6590141
6871447	6187321	7037687	6989235	6743799	7064256	6355862
6470625	7267825	6551828	7022473	6310035	7067727	7087810
6311426	6808709	6709863	6303330	6559176	7112728	7009092
6944988	6589534	6277625	6599739	6780890	7112729	6765130
7013601	6203786	6713292	6686192	7196057	7115802	6787685
7213367	6296879	6207436	6329141	6924268	7129401	6916974
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6776960	7153667	7264951	6809064	6359201	6603064	6689941
6841128	6251592	6627420	6844294	6410829	7166779	6320101
6375903	6617163	7083968	6440901	6426452	7166780	7115796
6432360	6335184	7252975	6221808	6677508	7214863	6906239
6254830	6333151	6348331	7041625	6743970	6420637	6521818
6280722	6410223	6764835	6884759	6747193	6433262	7199279
6503500	6780593	7262035	6184182	6750384	6444884	6867349
6419922	6706481	7211382	7060656	6753464	6459022	6730827
6495133	6764837	6818395	6417139	6756529	6476299	6512166
6962705	6316192	6168942	6838415	6759577	6492581	6187991
7045123	6869786	6410299	7151075	6777596	6806409	7238858
6280719	6180390	6875603	6346503	6777597	6806410	7064245
6913751	6235517	7135331	7109148	6777598	6809244	6492575
7029667	6344338	6372484	7001869	6781041	6812388	6369294
6423310	7186560	6777210	6413910	6784347	6858786	7005561
6451323	6358742	7129066	6387849	6794563	7141724	6255554
6544512	6183998	7226772	6432881	6797868	7161070	6518482

6348197	7122331	7081342	6544927	6800796	7164065	6486385
6251390	6787338	7125669	6919299	6806407	7166778	6492579
7118739	7160702	7205112	6762152	6809241	7169981	6495744
6338846	6893854	7060462	6472349	6809242	7173171	6784344
7153511	6509160	6228623	6506708	6831215	7173172	7115800
6258356	6878548	6846658	6310005	6858785	7179969	7259291
6521239	6258602	7189503	6284709	6891090	7186899	7135608
6264942	6358679	6472209	6797672	6897360	7205460	6946589
6645497	7270958	6821730	6881706	6897364	7208660	7276646
6713063	6794176	6225106	6569807	6900378	7220900	6992235
6599503	6645754	6534292	6444612	6909038	7279624	7135611
7211260	6277607	6706522	6764979	6911587	6420628	7115795
6447770	6294323	6699668	6204222	6914178	7115798	6388171
6998120	7026141	7049100	6566307	6924421	6316699	6538177
6699479	6794190	6268141	6841516	6927326	6320097	6822140
6294184	6777229	6905878	6579830	6930229	6627799	6897355
6468523	7094544	7262006	6790810	6965063	6759573	6242667
7078035	6890718	7098031	6174837	6969789	7256328	6262341
6764684	6329178	6280999	6329320	6974899	7273966	6881878
6306400	6235475	6524856	6831039	6979763	6864405	7112722
7238350	6352828	7026162	6887827	6982371	6215051	7271318
6793927	7273697	6509156	6271178	6984778	6967264	6548736
6180098	6270962	6465183	6413906	6995304	6407313	6927323
6852319	6783934	6924112	6235680	6995305	7081564	6596929
6221360	7087426	6872532	6489269	7005566	6376748	7078584
6500425	6524794	7273730	6514914	7009094	6380460	6924416
6416764	6696253	6210932	6586368	7012176	6380461	6872869
6331303	6635419	6207423	6300281	7015385	6403861	6930227
6495145	6852494	6506577	7012042	7019200	6441275	6211429
6752992	6271011	6750022	6313071	7049499	7186900	6229069
6833133	6667164	6514700	6310007	7102063	7084333	6949692
7041299	6951729	6838267	6759371	6610908	7084334	7049489
6455079	6586252	7267950	6475957	6515206	7166785	6791008
6368594	6387620	6680185	6444619	6891086	7253338	7067712
6221362	6190890	7070927	6465395	6677506	6949694	6444880
6455036	7014997	6723562	7074742	7164057	6528706	6429358
6746682	6420117	7094539	6806230	6797867	6359199	6677500
6180112	6645747	6942996	6221809	6734347	6515199	7132586
7144580	7273737	6753182	6762151	7138568	6395964	6911576
6217870	6602695	6773919	7056864	6271444	6586658	7238854
6514495	6982144	6492168	6358886	6245970	6635804	6229066
6183740	6297042	6844158	6323154	7098386	6642436	6590140

7270825	6632611	6326174	7211545	7098387	7098380	6906238
6372247	7214490	6846631	6908885	6960709	6441278	6355864
6689358	6218152	6365390	6172004	7098389	6806399	6262336
6866852	6448017	6416977	6521568	6946586	7230162	6300547
6471962	6300114	6489100	6228806	6737565	6849778	6774279
6406702	6667170	6743629	6569810	6835877	7084321	6797860
6500435	6232122	6759226	6245714	6765129	6784341	7189891
6689356	6432638	7214489	6815398	6429362	7217855	6617497
7029681	6485940	7091019	6448205	7256324	7057087	6320104
6896883	7262031	7217542	6500783	6372965	7247768	6525244
6261592	7056671	6830889	6821926	7105721	7235712	6855867
6337085	7056703	6368803	6284710	6664447	6906243	6844485
7211248	6713255	6492148	6559099	6670526	6531647	6194632
6783764	6451563	6706519	7101828	6555732	6376752	6316695
6500438	6455275	6312893	6576596	6268553	6756526	6743967
7018640	6821734	6623928	6548450	7169975	6215042	6225525
7211265	6790605	7247434	6180568	6906248	6563017	7098383
6406690	6867001	6365407	7105471	6677503	6350935	6452066
6770303	6197542	7041443	6774086	6872872	6407312	6175060
7244434	6251634	6730499	6271174	6320107	6812378	6703542
6974577	6858385	7279275	7056865	6172283	6559358	7238865
6303130	7141403	6306597	6524999	6414225	6215045	6737559
6261563	6534293	7226764	7056862	6300543	7166783	6455754
6521231	6617108	6635472	6586369	6717033	6495742	6881877
7070772	6582900	6682918	6867169	7094950	7238866	6372955
6730306	6337204	6440720	6699818	7282622	6222098	6956148
6780405	6255078	6613547	6632774	6329574	6476295	6316698
6193988	6569680	6323001	6329319	6297430	6800791	6897357
6410031	7244566	6420107	6352959	6875905	7154031	7262336
6475503	6368805	6294325	6200935	6399855	7164068	6828477
7037506	7052842	6872524	6750178	7179966	7176365	6784351
7029664	6376184	6184017	6642180	7189897	7179972	6740794
6235278	6465217	6630339	6323155	7262344	7183471	6635802
6335008	7041447	7198897	6569805	7041886	7186901	6211427
6680061	6331428	6566048	6872690	7094956	7186903	6472583
7150873	6429014	7049104	6235684	7098390	7186904	6274788
6541010	6344356	7217571	6841515	7262347	7186906	6180855
6464984	6797507	6358713	7153815	6476291	7189903	6215039
6521235	6593116	6475719	6680283	6392121	7189904	7109391
6270800	6913911	6861223	6756343	6984776	7193143	6974893
6399074	6210928	6482632	6706663	7041884	7199290	6630613
6326001	7238479	7223544	6200933	6492578	7199291	6639122

6576243	7282361	6174667	6265346	7049498	7205464	6867353
6733786	6576467	6323015	7141531	6822144	7208661	7244878
6596280	6335188	6756218	7030063	6235974	7208662	7250560
6203801	6649382	7176009	6656884	6323395	7211716	6278040
6517856	7041488	6312906	6967187	6506964	7211717	7279618
7060282	6383742	7135290	6900161	6506965	7217871	6809239
6322781	7250275	7108968	6838414	6646188	7217872	7115794
6803041	6303343	6498013	6268311	6426447	7217873	6353151
7226604	6794133	6750014	6841519	7053267	7223908	6995298
6403097	7175982	6376181	6770595	6603062	7232943	7038108
6177075	6242257	6660480	7122506	7122726	7232944	6541680
6372212	6197506	6451535	6602827	6258999	7232945	6781029
6248333	6203978	6962778	6759370	6703539	7235720	7193132
6534066	6645720	6821724	7271129	6310274	7235722	6414221
7029682	6458559	6946271	6180565	6713665	7235724	6914175
7232565	6355432	7026158	6734142	6392127	7235725	6861572
6280720	6451536	7250289	7244692	6727412	7235726	6204432
6350454	6964870	6316193	6534446	6365802	7241944	6248936
6713071	7083929	6242188	6372693	6380462	6969783	7199284
6251404	6218118	6448047	6277790	6248938	6833490	7148407
6207167	6544739	6692915	6440900	6262344	6747194	6653526
6303118	6225065	6770462	6350718	7173166	6809243	7053268
6896884	6541207	7135289	6767865	6320099	6310271	7074983
6280721	6677146	7083976	6617281	7285701	6433260	6713664
6270760	6660497	6284469	6348435	7045684	6444881	6469229
6841165	6699713	6287814	6291400	6235975	6469233	7141716
7166290	6410275	6733972	6992044	6313382	6469234	6268545
6921535	6284455	6268128	7071147	6818811	6476298	6444871
6287554	7118861	6337183	6258748	7030294	6617500	6300546
6187320	6322966	6503721	6297195	6184445	6624345	7026525
6410033	RE039885	7026123	7273831	6188001	6627800	6444876
6982095	6514699	6528264	6221810	6259004	6632986	7041872
6451321	7217522	6274340	6838416	6313381	6632987	6455755
6322780	7056739	6955912	6399541	6313383	6642440	6852910
6592874	6303326	7141398	6191071	6313384	6653537	7122723
6524588	6468742	6399323	6387848	6316702	6660916	7250562
6723324	6989249	6720137	6316390	6316703	6677509	6372959
7090854	6492142	7244564	6235681	6316704	6686519	6281408
6471977	6344345	6440700	6593274	6333453	6686520	7271311
6699490	7037696	6361951	7232792	6388179	6747195	6462254
7060264	6699654	7049068	6562759	6433259	6797869	6784336

RE039238	6939699	6319707	6645914	6693231	6812386	6642435
6908620	6280930	6921643	6191072	6700041	6831216	6720473
6998127	6303298	6815198	6677277	6706954	6835878	6916972
6531135	6391552	7189549	6451737	6717036	6835879	7135622
7270823	6531316	7264927	6642176	6717037	6838601	7217863
6183736	6492176	6635453	6831041	6717038	6852914	6927318
7244432	6916647	6403342	6743754	6717039	6852915	6271435
6719979	6555349	7211389	6670306	6717040	6884930	6344600
6491921	6376183	6174671	6407039	6720486	6906250	7067720
7261886	6916616	6340567	6458747	6720487	6909036	6858773
6444203	7033764	6759244	6472350	6723900	6909037	6570061
6296852	7052847	7109025	6303541	6723902	6911588	7227052
7153512	7056661	6607899	6451738	6723903	6933426	6943277
7198793	7056676	6623954	7271130	6727413	6946590	6441271
6610305	6933121	6500619	6613718	6730834	6956152	7071381
6596271	7238500	7135337	6525000	6730835	6989476	6313377
6254884	6423488	7223587	7049271	6730836	6989477	7112716
6264957	7122309	6846632	6248693	6730837	7002063	7154027
6306443	6500616	6656731	6410485	6734348	7002064	6613958
6951650	6251674	6514697	6479434	6737566	7022903	7135613
6482388	6287862	6265170	6667277	6740795	7057100	6632978
6713073	6326204	6759233	6326333	6740796	7094955	7067715
6881411	6335198	6312912	6756341	6740798	7109404	7064243
7087239	6352859	6287771	6593277	6747196	7112730	
6746672	6379964	7115376	6933261	6756528	7135629	

APPENDIX B

AGRICULTURAL RESEARCH FUNDING IN THE PUBLIC AND PRIVATE SECTORS, 1970-2008

Year	Public R&D funding (nominal dollars)	Private R&D funding (nominal dollars)	R&D deflator (2001=1)	Public R&D funding (2001 dollars)	Private R&D funding (2001 dollars)	Total agricultural R&D (2001 dollars)
1970	514,437,000	464,300,000	0.2037	2,525,485,639	2,279,351,956	4,804,837,595
1971	553,299,000	487,100,000	0.2154	2,568,465,525	2,261,163,597	4,829,629,122
1972	639,624,000	507,400,000	0.2256	2,835,113,009	2,249,034,340	5,084,147,349
1973	665,388,000	576,100,000	0.2393	2,780,215,396	2,407,140,029	5,187,355,426
1974	729,310,000	669,290,000	0.2574	2,832,916,771	2,599,776,316	5,432,693,087
1975	825,141,000	708,540,000	0.2763	2,986,760,271	2,564,700,000	5,551,460,271
1976	896,505,000	817,780,000	0.2941	3,047,997,907	2,780,343,365	5,828,341,272
1977	1,018,250,000	953,950,000	0.3064	3,323,455,118	3,113,587,047	6,437,042,165
1978	1,100,244,000	1,079,109,000	0.3243	3,393,069,235	3,327,890,495	6,720,959,730
1979	1,218,999,000	1,204,080,000	0.3481	3,502,116,990	3,459,255,524	6,961,372,514
1980	1,350,158,000	1,453,024,000	0.3788	3,563,893,243	3,835,419,570	7,399,312,812
1981	1,487,113,000	1,468,190,000	0.4151	3,582,386,731	3,536,802,095	7,119,188,826
1982	1,644,913,000	1,651,512,000	0.4481	3,670,783,322	3,685,509,632	7,356,292,953
1983	1,703,057,000	1,794,203,000	0.4743	3,590,998,088	3,783,184,909	7,374,182,997
1984	1,794,348,000	2,045,965,000	0.5012	3,580,036,679	4,082,056,404	7,662,093,082
1985	1,910,950,000	2,167,210,750	0.5287	3,614,525,574	4,099,237,907	7,713,763,481
1986	2,028,770,000	2,320,865,000	0.5577	3,638,046,068	4,161,838,843	7,799,884,911
1987	2,104,587,000	2,278,197,000	0.5920	3,554,797,331	3,848,036,985	7,402,834,316
1988	2,235,778,000	2,571,360,000	0.6153	3,633,762,310	4,179,176,579	7,812,938,889
1989	2,418,949,000	2,745,153,000	0.6492	3,726,270,696	4,228,771,743	7,955,042,439
1990	2,575,529,000	2,971,347,000	0.6843	3,763,520,027	4,341,913,425	8,105,433,452
1991	2,704,622,000	3,172,941,000	0.7145	3,785,537,679	4,441,022,705	8,226,560,384
1992	2,851,866,000	3,207,266,000	0.7380	3,864,299,527	4,345,869,156	8,210,168,683
1993	2,949,273,000	3,463,213,000	0.7705	3,827,512,073	4,494,493,920	8,322,005,993
1994	3,081,172,000	3,556,593,000	0.7962	3,869,958,025	4,467,087,726	8,337,045,751
1995	3,149,886,000	3,884,896,000	0.8195	3,843,572,829	4,740,451,149	8,584,023,978
1996	3,144,224,000	3,960,789,000	0.8428	3,730,735,640	4,699,619,583	8,430,355,223
1997	3,229,904,000	4,381,220,000	0.8668	3,726,261,923	5,054,507,274	8,780,769,197
1998	3,353,099,000	4,559,514,000	0.8936	3,752,480,817	5,102,589,819	8,855,070,636
1999	3,542,147,000		0.9270	3,820,996,991		n.a.

2000	3,796,192,000		0.9592	3,957,756,456		n.a.
2001	4,094,008,000		1.0000	4,094,008,000		n.a.
2002	4,477,435,000		1.0305	4,344,848,941		n.a.
2003	4,597,804,000		1.0608	4,334,175,937		n.a.
2004	4,790,690,000		1.0967	4,368,383,864		n.a.
2005	4,873,511,000		1.1388	4,279,343,799		n.a.
2006	5,296,333,000		1.1901	4,450,492,360		n.a.
2007	5,285,128,000		1.2367	4,273,401,371		n.a.
2008	5,240,433,000		1.3008	4,028,504,672		n.a.

Note: Data for 2007-08 are preliminary.
Dollars here refer to the U.S. dollars

Source: USDA, ERS based on data from National Science Foundation, USDA's Current Research Information Systems (CRIS), and various private sector data sources. Data are adjusted for inflation using an index for agricultural research spending developed by ERS. See the documentation for details.

APPENDIX C

PATENT STATISTICS CHART (APPLICATIONS AND GRANTS)

CALENDAR YEARS 1963 - 2010

Year of Application or Grant	Utility Patent Applications, U.S. Origin	Utility Patent Applications, Foreign Origin	Utility Patent Applications, Foreign Origin Percent Share	Utility Patent Applications, All Origin Total	Design Patent Applications	Plant Patent Applications	Total Patent Applications
1976	65,050	37,294	36.4	102,344	7,061	175	109,580
1977	62,863	38,068	37.7	100,931	7,258	188	108,377
1978	61,441	39,475	39.1	100,916	7,538	194	108,648
1979	60,535	39,959	39.8	100,494	7,519	196	108,209
1980	62,098	42,231	40.5	104,329	7,830	220	112,379
1981	62,404	44,009	41.4	106,413	7,375	178	113,966
1982	63,316	46,309	42.2	109,625	8,174	188	117,987
1983	59,390	44,313	42.7	103,703	8,082	255	112,040
1984	61,841	49,443	44.4	111,284	8,739	253	120,276
1985	63,874	53,132	45.4	117,006	9,551	231	126,788
1986	65,487	56,946	46.5	122,433	9,912	320	132,665
1987	68,315	59,602	46.6	127,917	11,153	385	139,455
1988	75,192	64,633	46.2	139,825	11,289	377	151,491
1989	82,370	70,380	46.1	152,750	12,615	383	165,748
1990	90,643	73,915	44.9	164,558	11,288	418	176,264
1991	87,955	76,351	46.5	164,306	13,061	463	177,830
1992	92,425	80,650	46.6	173,075	13,078	354	186,507
1993	99,955	74,788	42.8	174,743	13,635	361	188,739
1994	107,233	82,624	43.5	189,857	15,774	459	206,090
1995	123,958	88,419	41.6	212,377	15,409	452	228,238
1996	106,892	88,295	45.2	195,187	15,161	665	211,013
1997	120,445	94,812	44	215,257	16,546	621	232,424
1998	135,483	107,579	44.3	243,062	17,107	720	260,889
1999	149,825	120,362	44.5	270,187	17,761	863	288,811
2000	164,795	131,131	44.3	295,926	18,292	797	315,015

2001	177,511	148,997	45.6	326,508	18,280	944	345,732
2002	184,245	150,200	44.9	334,445	20,904	1,144	356,493
2003	188,941	153,500	44.8	342,441	22,602	1,000	366,043
2004	189,536	167,407	46.9	356,943	23,975	1,221	382,139
2005	207,867	182,866	46.8	390,733	25,553	1,222	417,508
2006	221,784	204,183	47.9	425,967	25,515	1,151	452,633
2007	241,347	214,807	47.1	456,154	27,752	1,049	484,955

Year of Application or Grant	Utility Patent Grants, U.S. Origin	Utility Patent Grants, Foreign Origin	Utility Patent Grants, Foreign Origin Percent Share	Utility Patent Grants, All Origin Total	Design Patent Grants	Plant Patent Grants	Reissue Patent Grants	Total Patent Grants	Total Patent Grants, Foreign Origin Percent Share
1976	44,280	25,946	36.9	70,226	4,564	176	422	75,388	
1977	41,484	23,785	36.4	65,269	3,929	173	410	69,781	36
1978	41,255	24,847	37.6	66,102	3,862	186	364	70,514	37
1979	30,078	18,776	38.4	48,854	3,119	131	309	52,413	37
1980	37,355	24,464	39.6	61,819	3,949	117	285	66,170	38
1981	39,223	26,548	40.4	65,771	4,745	183	365	71,064	39
1982	33,896	23,992	41.4	57,888	4,944	173	271	63,276	40
1983	32,871	23,989	42.2	56,860	4,563	197	362	61,982	41
1984	38,367	28,833	42.9	67,200	4,938	212	300	72,650	42
1985	39,555	32,106	44.8	71,661	5,066	242	276	77,245	44
1986	38,126	32,734	46.2	70,860	5,518	224	260	76,862	45
1987	43,520	39,432	47.5	82,952	5,959	229	245	89,385	47
1988	40,497	37,427	48	77,924	5,679	425	244	84,272	47
1989	50,185	45,352	47.5	95,537	6,092	587	317	102,533	47
1990	47,391	42,974	47.6	90,365	8,024	318	370	99,077	47
1991	51,177	45,334	47	96,511	9,569	353	263	106,696	46
1992	52,253	45,191	46.4	97,444	9,269	321	360	107,394	45
1993	53,231	45,111	45.9	98,342	10,630	442	332	109,746	44
1994	56,066	45,610	44.9	101,676	11,095	499	317	113,587	43
1995	55,739	45,680	45	101,419	11,712	387	316	113,834	43
1996	61,104	48,541	44.3	109,645	11,410	362	279	121,696	43
1997	61,708	50,276	44.9	111,984	11,414	394	277	124,069	44
1998	80,289	67,228	45.6	147,517	14,766	561	298	163,142	44
1999	83,905	69,580	45.3	153,485	14,732	420	448	169,085	44
2000	85,068	72,426	46	157,494	17,413	548	524	175,979	45
2001	87,600	78,435	47.2	166,035	16,871	584	480	183,970	46
2002	86,970	80,360	48	167,330	15,451	1,133	460	184,374	47

2003	87,893	81,130	48	169,023	16,574	994	421	187,012	47
2004	84,270	80,020	48.7	164,290	15,695	1,016	298	181,299	48
2005	74,637	69,169	48.1	143,806	12,951	716	245	157,718	48
2006	89,823	83,949	48.3	173,772	20,965	1,149	519	196,405	48
2007	79,526	77,756	49.4	157,282	24,062	1,047	508	182,899	49

Except for percent share and year, the remaining variables in the above two tables all refer to patent quantity

Source: U.S. PATENT AND TRADEMARK OFFICE

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